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JAMES ROBERT WEIR
1881–1943

JOHN A. STEVENSON

James Robert Weir was born May 31, 1881, on a farm near Scottsburg, Indiana, and at his own request was buried there, following death from a cerebral hemorrhage on June 1, 1943. Dr. Weir was a descendant of Scottish immigrants, who came to the Ohio Valley from the Carolinas by way of Tennessee. As a farm boy he early became interested in the wild life about him, both plant and animal, and even prepared a manuscript treatise on "The natural history of Scott County" at the tender age of ten, although few books except an early edition of Wood's Botany and Dana's Geology were available to him. He graduated from the Scottsburg High School in 1900 and then attended the University of Indiana for several terms.

Wanderlust overtaking him, he worked for a time with forest survey parties in Alabama and Tennessee, taking part in some of the early reconnaisance surveys engaged in preparing forest working plans for the then Bureau of Forestry. Between seasons he matriculated at Purdue University as a special student, pursuing courses in botany under the noted botanists Stanley Coulter and J. C. Arthur. He finally returned to Indiana University where he remained until graduation in 1907 with an A.B. degree in botany.

He began his professional career as instructor in biology and chemistry at Culver Military Academy, serving in that capacity for two years. The spring of 1909 found him rambling through Central Europe botanizing and studying French and German. He entered the University of Munich in the fall, studying under Goebel in botany, Tubeuf in forest pathology, and Hertwig in zoology and receiving the Ph.D. degree in May, 1911. His doctoral dissertation dealt with the genus *Coprinus* in its morphological and physiological aspects.

Returning shortly thereafter to the United States, he almost immediately accepted a position as forest pathologist with the Office of Forest Pathology, Bureau of Plant Industry, U. S. Department of Agriculture. During the ensuing ten years, in cooperation with the United States Forest Service, he carried on pioneer investigations with forest tree diseases in the forests of the Northwest. His headquarters, originally at Missoula, Montana, were later transferred to Spokane, Washington, a number of years before his transfer to Washington, D. C., in 1921.

During this time—a fruitful period in his career—he published between 70 and 80 notes, bulletins, reports, and miscellaneous papers covering the results of his observations and researches on the problems encountered in his field. These papers, many of them in collaboration with his associate, E. E. Hubert, and some with the help of Annie Rathbun-Gravatt and Arthur S. Rhoads, covered a wide range of forest mycology and pathology, including

descriptions of new fungi found associated with tree diseases, records of forest tree disease surveys, studies of wood-rotting fungi, and life history studies of tree rusts and other forest fungi. Especially noteworthy were his extensive studies of the mistletoe parasites (the genus *Razoumofskya*)

JAMES ROBERT WEIR
1881–1943

of the forest trees of the Northwest. He gave particular attention to the development of methods of prevention and control of tree diseases as part of standard forest management practices. An indefatigable collector, he built up in the course of his work a comprehensive herbarium of fungi, including

not only those encountered in the forests through which he worked, but a valuable series obtained by exchange with mycologists throughout the world. This collection, notably rich in the Polyporaceae and other wood-inhabiting Hymenomycetes, now forms part of the mycological collections of the Bureau of Plant Industry.

With the closing of the Spokane laboratory in 1921, Dr. Weir came to Washington to write up that portion of his work remaining unpublished and was then transferred (1923) to assume charge of the mycological collections of the Bureau. His work with this unit was interrupted by extensive field trips.

During 1923 as pathologist, he was a member of the joint expedition of the Departments of Agriculture and Commerce to study the rubber production possibilities of the Amazon Valley of Brazil and Bolivia. During the course of this work a very large and important collection of fungi was made, including not only those concerned with diseases of *Hevea*, but all that he could find causing timber rot and disease of economic trees in the area covered. A comprehensive publication covering all known *Hevea* diseases and fungi resulted from this work. Following this expedition he travelled extensively in Argentina, Paraguay, Chile, and the West Indies, continuing intensive studies of diseases of tropical plants. Before resuming his work in Washington he spent two months in Cuba with the Sugar Experiment Station of the Tropical Plant Research Foundation where attention was given to sugar-cane-disease research and the possibilities of controlling marabu, a leguminous weed tree.

Early in 1927, the then newly organized Rubber Research Institute of Malaya invited Dr. Weir to join the staff as Head of the Department of Plant Pathology at Kuala Lumpur. Here he spent two years organizing work in his field. There followed a period of service as Director of the Plant Research Department of the Goodyear Rubber Plantations Co., Sumatra, Dutch East Indies. With broadened interests he established new silvicultural management practices for rubber lands, and studied improved tapping methods rather than confining his efforts to the purely pathological aspects of the crop as he had done, perforce, while working in Malaya. He took an active part in the Company's program of planting 40,000 acres of budded, high-yielding clones on its new Wingfoot Estate and investigated other tropical crops including tea, tobacco, coffee, sisal, and Manila hemp.

Returning to America late in 1932, planning to resume his studies in the taxonomy of the fungi, he was soon back in tropical harness with the Ford Motor Co., as an agricultural advisor of this concern on its Fordlandia and Belterra plantations along the Tapajoz River, a tributary of the Amazon. Here he found that extensive plantings had been made by transplanting wild seedlings without consideration for disease resistance or yield possibilities. His experience in the Orient had demonstrated clearly that whereas, "run of the mine" seedlings would yield only from 200 to 400 pounds per acre per year, selected clones with which he had worked would produce 700 pounds and even as high as 1500 pounds or more.

So within a few months he was back in the East Indies, buying selected plants of *Hevea* budded from the choicest high-yielding clones. Two thousand plants were finally secured, making a shipment of several tons in weight, all packed in specially built wardian cases and transshipped to Brazil with much care. He finally sailed up the Amazon and the Tapajoz with this material in the spring of 1934, some 58 years after Sir Henry Wickham had sailed down the same Rivers with his history-making collection of *Hevea* seed. It is of further interest to note that the Belterra plantation lies just across the Tapajoz River from the town of Boim, near which Wickham collected his seed. Some 1200 of Weir's plants survived in the nursery of Belterra to form the basis of subsequent large scale field plantings. And soon thereafter the International Rubber Committee in Singapore "locked the stable" by an order forbidding export of *Hevea* planting material in any form from territory under its control!

Following his service with the Ford Co., which terminated in March, 1938, Dr. Weir travelled extensively in Brazil and other countries of South and Central America with rubber-producing possibilities, studying *Hevea* cultivation and diseases and other complementary crop plants. During the years 1940–41 he was agricultural advisor to the Government of Venezuela with particular attention to increased rubber production. Death found him living quietly in retirement on the old home farm.

Dr. Weir was a member of many technical organizations during his active career in forest pathology, among which were the American Phytopathological Society, American Association for the Advancement of Science, Botanical Society of America, Society of American Foresters, Torrey Botanical Club, Ecological Society of America, and American Genetic Association.

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LYGUS BUG INJURY OF LIMA BEAN IN CALIFORNIA

KENNETH F. BAKER, WILLIAM C. SNYDER, AND A. H. HOLLAND[1]

(Accepted for publication February 19, 1946)

There occurs commonly in California a necrotic pitting of seeds of lima bean and blackeye cowpea which closely resembles the yeast spot reported in pathological literature except for the fact that no pathogen occurs in the lesions. Evidence is presented in this paper that the injury in California results from the feeding of Lygus bugs on the developing seed, substantiating an earlier note (2).

Large and baby lima beans and blackeye cowpeas in Ventura, Merced, San Joaquin, and Stanislaus counties and large limas in Orange and Los Angeles counties commonly have this trouble, and it also is said by W. W. Mackie to occur on cowpeas in Imperial County. It is referred to by growers and shippers as yeast spot, aphid spot, seed puncture, seed pitting, or dimpling. Nearly the entire dry large and baby lima crop of the United States (98.4 per cent in the period, 1934–43) is grown in California on about 150,000 acres of land in Ventura, Orange, Merced, San Joaquin, Stanislaus, San Diego, Los Angeles, and Santa Barbara counties. Green limas for fresh market and freezing are grown to a less extent in Los Angeles, Santa Clara, Orange, Lake, Stanislaus, and Ventura counties, occupying about 3,000 acres.

Losses from Lygus feeding result from: (a) shedding of blossoms and young pods; (b) discarding beans having conspicuous pits, or lowering of grade in fresh and frozen lima beans, particularly the latter, if such seeds are not removed; (c) cost of hand removal of pitted seeds from dry beans and from fresh limas to be used for quick-freezing; (d) occasional withering of the affected bean in an otherwise normal pod. The amount of actual loss sustained is uncertain because of the difficulty of comparison between fields and because the reduction in number or size of pods or beans may result in some size increase in the remaining beans. Also, plants with severe shedding of flowers and pods often continue to flower and may set a late crop of pods; in some cases such as in the Modesto area this late crop may mature, although tardily, but in other areas such as Ventura the bugs remain active in green fields and no late crop can be set. The injury frequently is so severe in local areas that the crop does not pay the cost of harvesting.

This seed pitting apparently was first observed in Michigan in 1895 on common bean (3) and definitely attributed to Lygus feeding. This association was reaffirmed in New York in 1919 (9) and was reported in Idaho in 1930 (20) where it also occurred on lima bean. The injury was said (1) to have occurred in California dried limas sold in Illinois in 1922 and was

[1] The writers acknowledge with pleasure the helpful suggestions of Dr. A. E. Michelbacher on some entomological phases of the study, and of Dr. P. G. Hoel on the statistical techniques used. Mr. A. A. Peukert, Oxnard, kindly supplied the plants analyzed in table 2.

attributed to yeast, apparently on the basis of symptoms. The pitting was first definitely associated with Lygus bug in California in 1944 by the writers. Fields with severe seed pitting and pod shedding frequently had large populations of these insects and were near recently cut alfalfa fields or other sources of infestation. Pods which contained pitted seed often had spots of sticky Lygus excrement. Examination of seed lesions failed to reveal *Nematospora* or other pathogens. It is known that Lygus bugs injure alfalfa (23), beet (10), and cotton (5) seeds, that they cause seed pitting of various beans (3, 9, 20) and that the insects feed on flowers and fruits or seeds. The demonstrated fact that these bugs are highly toxicogenic (21; 22, pp. 164–166) is consistent with the type of injury, a tissue breakdown rather than a mere puncture.

A similar type of injury to lima bean and blackeye cowpea was observed in Virginia in 1921 associated with the yeast, *Nematospora coryli* Pegl. (*N. phaseoli* Wingard), which was carried by the southern green stinkbug, *Nezara viridula* L. (*N. hilaris* Say) (29, 30). Such a relationship had first been shown by Nowell (16) in 1917 for internal boll disease of cotton. Yeast spot of lima bean has been reported in this country from Alabama (30), Illinois (1, 30), Maryland (8), Mississippi (8), North Carolina (8), Tennessee (30), Virginia (30), and West Virginia (14), as well as from Puerto Rico (8), Belgian Congo (24), Bermuda (26), and the West Indies (17). In addition, yeast spot has been reported in Oklahoma (13) on soybean and in South Africa (15) on kidney, mung, sugar, and soybeans and *Bauhinia golpini*. Other legumes reported as hosts include string bean (26), cowpea (17, 24, 29), bird's eye bean (29), and *Vigna catjang, V. unguiculata, Dolichos lablab, Canavallia gladiata, Crotalaria juncea, C. retusa,* and *Tephrosia, Indigofera,* and *Cassia spp.* (17). *Nematospora spp.* have been reported causing "stigmatomycosis" on fruits of a number of other hosts (tomato, cotton, pepper, orange, grapefruit, tangerine, pecan, *Datura metel, Asclepias curassavica,* pomegranate, coffee, *Sterculia platanifolia,* etc.) in association with several plant bugs. The only record of *N. coryli* in California in connection with an established plant disease apparently is that of Fawcett (6) on citrus, pomegranate, and cotton, although Schneider (19) found it on imported tomatoes here.

SYMPTOMS

The type of symptom produced on lima bean depends on the stage of pod and seed development at the time of Lygus feeding. If this occurs on blossoms or young pods they are quickly shed. Pods up to 2 inches or more in length commonly turn yellow, wither, and drop; these are referred to by growers as "buckskins" and attributed to high temperature. These symptoms resemble those which result from feeding of the green stinkbug, as illustrated by Underhill (25). Shedding may involve only a low percentage of the total pods set if only part of a field is infested or the infestation occurs tardily, or losses may be severe. In Ventura County in 1944 vining limas

in a 10-acre strip adjacent and parallel to a recently cut alfalfa field had, because of Lygus injury, set essentially no pods and were not threshed (11).

At the time of puncture of the pod a small hole may be visible from which sap oozes, and internally the tissue surrounding the puncture soon turns brown (20). External symptoms on such pods are lacking. Older pods have smooth, firm intumescences up to 10 mm. across and 2 mm. high on the inside surfaces (Fig. 1, A); such swellings have been reported from feeding of Lygus bugs on cotton stems (12) and bolls (5). These intumes-

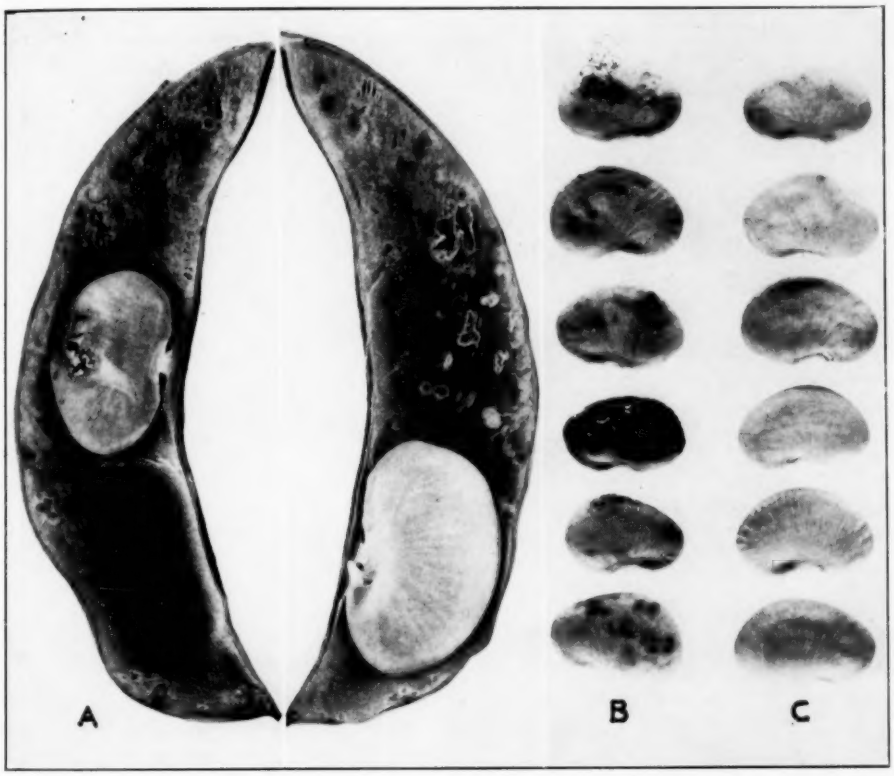

FIG. 1. Lygus injury of Ventura vining type lima bean produced by caging the bugs on plants grown in the greenhouse, 1945. A. Pod showing injuries and intumescences on inner surface of walls, and a pitted seed. B. Beans from pods on which Lygus were caged. C. Beans from pods on same plants caged without the insects.

cences frequently cause distortion by pressure against the developing seeds and usually are in contact with pitted areas of a seed. An occasional lack of coincidence is not surprising because (a) not all feeding punctures occur near seeds nor are all deep enough to reach a seed, and (b) changes in spatial relationship resulting from enlargement and crowding of seeds may destroy the coincidence of seed and pod punctures. The inside of a badly injured pod frequently has a frosty appearance from surface proliferation of parenchyma cells and the opposite walls of the pod sometimes fuse. As such pods mature a brown discoloration and tissue breakdown is visible on the inside

and, less definitely, on the outside. Examination of many pods has demonstrated the impossibility of accurately detecting either internal pod intumescences or seed pitting by external appearance of the pod, except by the infrequent incidence of slight swellings at the point of feeding.

In young seeds the initial injury may appear as a water-soaked area around a small hole; this soon shrivels to an irregular pit which probably enlarges as the seed grows. The seed may not attain normal size or may even shrivel, although the rest of the seeds in the pod are normal; other factors also cause such shriveling (Tables 1, 2). The pitted areas in full-

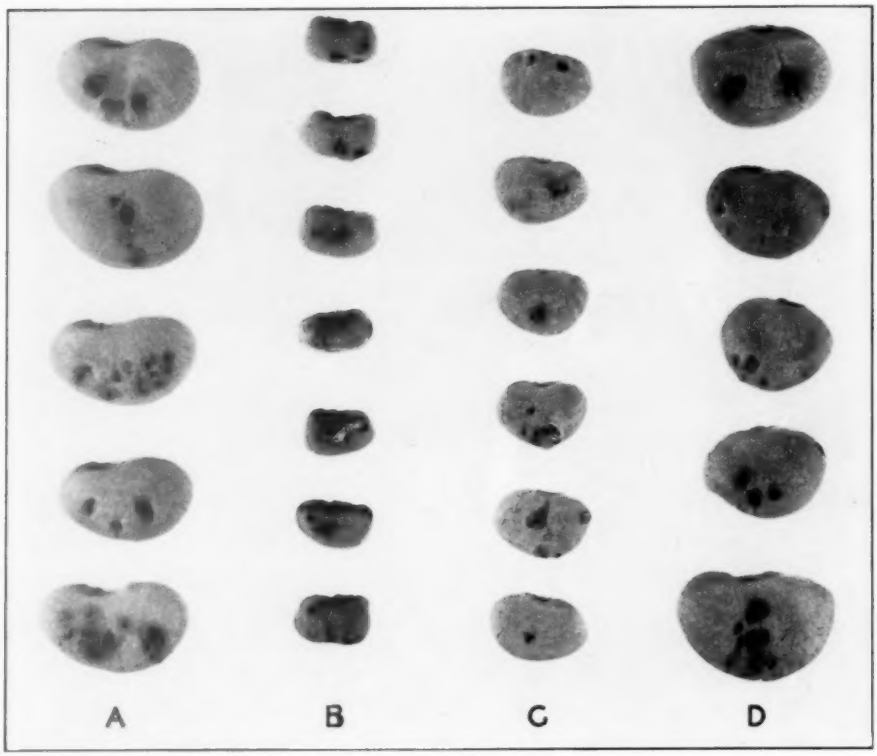

FIG. 2. Lygus pitting of field-grown lima bean and cowpea seed. 1944. A. Ventura vining type lima bean. B. Blackeye cowpea. C. Baby lima bean. D. Fordhook bush lima.

size beans vary from a tiny, sunken pin point, which may or may not rupture the testa, to large, irregular, crater-like, yellow or brown spots in the cotyledon over which the testa is destroyed. The tiny punctures without necrotic tissue apparently result from non-toxic feeding. Whether Lygus bugs vary in toxicity, as reported for other toxicogenic insects, is undetermined. The cavity is filled with a brown, granular, crumbly mass of necrotic cells and starch grains which is particularly evident before the seed dries. A similar necrosis from Lygus feeding has been reported on potato tubers (21, 22). Pits may occur at any point on the lima seed, singly or in such numbers that

coalescence results; as many as 52 punctures have been counted on a single seed. The testa may crack or even flake from dried beans, starting at such pits. Seed injury is shown in figures 1 and 2 and also in other papers (8, 20, 25, 29). Sometimes the integuments do not grow sufficiently to cover the uninjured cotyledons. This may represent (a) a gap left, by growth, when feeding killed a few cells of the very young integuments without injuring the cotyledons, or (b) a partial starvation of the integument tissue from injury to its vascular system in or near the funiculus. The second type could result from a feeding puncture which, had it occurred closer to the central vascular system of the funiculus, would cause the starvation or abortion of the entire seed.

Since the bugs are unable to feed on pods or seeds which have begun to toughen (20), and since feeding will cause shedding of young pods and abortion of young seeds, there is a relatively limited developmental period during which feeding will produce pitting of mature seeds. The percentage of seeds pitted may not, therefore, be high even in fields sustaining high total loss from the bugs. Shull (20) reported commercial fields of Great Northern beans with up to 4.09 per cent pitted seed and baby limas with up to 2.92 per cent.

Because Lygus bugs reach the highest population in mid- to late summer (20) the first pods set are relatively free of injury, but in cases of heavy later infestation essentially the total crop may be lost. Since the maximum damage occurs in the warmest season, the shedding of pods and flowers has been referred to as heat damage or, in the case of vining limas, as "steaming."

Microscopic examination of pitted areas has failed to reveal evidence of feeding tracks. This is in line with the absence of sheath material reported (12) in cotton on which various Miridae, including *Lygus oblineatus* (Say) (*L. pratensis* L.), had fed. Since the cells adjacent to the puncture usually are killed and shrunken, the continuity of sheath material would be destroyed.

SEED PITTING A RESULT OF LYGUS FEEDING

A number of circumstances in California differ sharply from those of the States reported to have *Nematospora* on lima beans. The yeast has been neither demonstrated in nor recovered from pitted lima bean seed grown here. The vector in the eastern area, the southern green stinkbug (*N. viridula*), apparently does not occur in the State. Beans are grown during the rainless summer months, a circumstance which practically eliminates seed infections by pathogens and would make for infrequent occurrence of *Nematospora*. Apparently these yeasts have only once (6) been reported causing a field disease in the State. Observations already presented caused the writers by August, 1944, to suspect Lygus bugs (*L. hesperus* Knight, *L. elisus* V.D., and perhaps others) as the true cause of the injury in California and subsequent work has confirmed this relationship.

Specimens of pitted blackeye cowpeas from Westley, California, large

limas from Ventura, and baby lima beans from Modesto, gathered in 1944 and submitted to W. E. Shull were found[2] to be identical with those produced by Lygus bugs in Idaho. The injury has not been observed on common bean in California. The Kentucky Wonder types of these beans with thick pod walls grown in Ventura, Santa Barbara, and Los Angeles counties would not be expected to show seed pitting, since Shull (20) found that it occurred only on thin-walled varieties.

A preliminary test with Lygus bugs collected near Oxnard in September, 1944, and caged on pods of lima beans growing in the field at West Los Angeles resulted in severe pod shedding after their feeding. As a consequence there was no seed pitting.

Insects collected near Ventura in September, 1945, were confined in cloth bags on clusters of flowers or young pods, and on older pods. The younger material was shed quickly in each case. When the older pods were examined after 7 days they contained typically pitted seed (Fig. 1) and the lesions were free from microorganisms.

TABLE 1.—*Incidence of seed pitting in lima beans grown in cloth cages with and without Lygus bugs. Insects added on July 31. Ventura County, 1945*

Location	Test condition	Lima bean seed				
		Total number	Average per pod	Per cent shriveled	Pitted	
					Number	Per cent
Oxnard (irrigated)	Lygus	688	1.86	30.2	36	5.2
	Check	596	1.83	32.4	0	0.0
Somis (unirrigated)	Lygus	1333	1.72	13.1	30	2.3
	Check[a]	1923	1.92	29.2	2	0.2
Camarillo (unirrigated)	Lygus	873	1.74	15.1	0	0.0
	Check	819	1.80	13.7	0	0.0

[a] An uncaged equivalent area of an adjacent row had to be used and accounts for the pitted beans in this series.

Aster-cloth cages were placed over 30-foot sections of rows of vining type lima beans in several localities of Ventura County prior to seedling emergence. On July 31, 1945, approximately 200 Lygus bugs from alfalfa were placed in one cage in each location and the other was left as a check. The cages remained in place until the vines were mature and cut. Pods were harvested and the seed hand threshed. The incidence of seed pitting and shriveling in these trials is shown in table 1. In the Oxnard and Somis series there were 5.2 and 2.3 per cent of the seeds pitted in the Lygus cages, and 0 and 0.2 per cent in the checks. In the Camarillo test no pitting occurred in either cage, possibly because of some unfavorable environmental factor. The shriveling of the seeds in these tests obviously was not associated with Lygus injury, and the incidence of these aborted seeds is indicative of some physiological cause of much of this type of injury in the field. That Lygus can produce it occasionally is not doubted.

[2] Personal communication of May 31, 1945.

Additional data were obtained incidentally from an experimental plot near Oxnard set up by Holland in cooperation with the Division of Entomology, California Agricultural Experiment Station, Berkeley, to determine whether DDT would control Lygus. A 16.8-acre field of bush type lima beans was observed in early July, 1945, to be badly infested with Lygus bugs which had migrated from a large adjacent planting of seed beets. The field was divided into 3 parts: a 6-acre strip 60 rows wide next to the beets (check 1), the next 6-acre strip dusted with DDT (30 lbs. per acre of 4 per cent dust in sulphur) on July 28, the last 4.8-acre strip (check 2). On October 2, the date the field was cut, 100 plants were removed from the center row of each plot, 10 consecutive plants being taken without selection from each of 10 equally spaced points in the row. Data on these plants are given in table 2.

TABLE 2.—*Data on lima bean plants from an area dusted once with DDT to reduce Lygus bug injury, and from the surrounding field. Ventura County, 1945*

Items measured	Two check plots		DDT plot		Difference[a]
	n	Mean[a]	n	Mean[a]	
Green pods per plant	200	1.65 ± 0.16[b]	100	3.01 ± 0.40	1.36 ± 0.43
Dry pods per plant	200	12.48 ± 0.46	100	19.90 ± 0.79	7.42 ± 0.91
Total seeds per plant	200	35.20 ± 1.29	100	61.60 ± 2.53	26.40 ± 2.84
Pitted seeds per plant	200	5.41 ± 0.41	100	3.04 ± 0.45	2.37 ± 0.61
Percentage seed unpitted	200	83.90 ± 1.13	100	93.10 ± 0.65	9.20 ± 1.30
Percentage seed shriveled	20	9.80 ± 1.37	10	15.20 ± 0.76	5.40 ± 1.57
Seeds per pod	20	2.56 ± 0.03	10	2.66 ± 0.04	0.10 ± 0.05[c]
Total dry weight per 10 plants (oz.)	20	34.60 ± 1.71	10	40.30 ± 2.26	5.70 ± 2.83[c]
Dry weight per 10 plants without pods (oz.)	20	16.20 ± 1.03	10	12.80 ± 0.77	3.40 ± 1.29
Dry weight of pods per 10 plants (oz.)	20	18.65 ± 0.91	10	27.80 ± 1.54	9.15 ± 1.79
Threshing seed yield per 10 plants (oz.)	20	14.00 ± 0.67	10	20.60 ± 1.11	6.60 ± 1.30
Threshing seed yield of pitted seed per 10 plants (oz.)	20	1.63 ± 0.20	10	0.90 ± 0.31	0.73 ± 0.37[c]

[a] Standard error given.
[b] Difference between check plots significant; remaining differences not significant.
[c] Difference not significant; remaining differences significant.

The only character showing a statistically significant difference between the two check plots was the number of green pods per plant. It is, therefore, justifiable to use a mean of the two plots for comparison with the dusted area. There were significantly more green pods, dry pods, and total seeds per plant, and a higher percentage of unpitted beans from the dusted than from the check areas. It might be argued that the given population of Lygus bugs had more pods on which to feed in the dusted than in the check areas, and that a smaller number of pitted seeds would therefore be expected. There was, however, no relationship between the number of pods per plant and the number of pitted seeds. The correlation coefficient for check 1 was 0.066 and was 0.074 for check 2; the correlation ratio for the dusted plot

was 0.111. This lack of correlation apparently resulted from the mobility of the insect. There was reduction in seed pitting and an increase in pod set, each independent of the other. There was a higher percentage of shriveled seeds in the dusted than in the check plots; this again suggests that Lygus bugs are not primarily responsible for seed shriveling.

The dusted plants were smaller than those from the checks but had a greater weight of pods, giving a total dry plant weight which was approximately equal. The weight of seed per 10 plants, cleaned so as to approximate field threshing, was likewise greater in the dusted than check areas; this apparently resulted mostly from increased pod set but somewhat from a slightly larger number of seeds per pod. The field-threshed yield was 20.31 bags per acre from the checks and 24.0 from the dusted area. A random sample of 650–800 beans was gathered directly from the threshing machine as it moved through each plot. These samples had 22.71 beans per ounce in the checks and 24.74 in the dusted plot. A test in another field yielded 21.06 and 23.0 bags per acre from the check and DDT plots, respectively, and these had 29.83 and 30.17 beans per ounce. The data indicate that there was little or no decrease in seed weight because of increased numbers.

One hundred green pods were gathered from one row of each plot on September 24 and examined carefully for Lygus damage. Check 1, check 2, and the dusted plot, respectively, had 84, 85, and 34 per cent of the pods with internal symptoms of Lygus feeding. The percentages of seed pitted were 53.4, 34.4, and 15.6, and the average number of seeds per pod were 3.11, 3.23, and 3.52, respectively. These data on green pods are essentially in line with those on the total crop, except that a much higher percentage of pitting was evident. Since the Lygus populations are highest late in the season, it seems reasonable that late setting pods would have more pitting.

These data may be interpreted as further evidence that Lygus bugs cause pod and blossom shed and seed pitting, and that control of the insects will reduce the amount of injury.

CONTROL

Since the reduction of Lygus injury is largely a matter of insect control, detailed methods are outside the scope of this paper. However, it may be mentioned that DDT has been found by several workers to be highly effective against these insects on various hosts. Also, field evidence suggests that the planting of lima beans next to a favored perennial host of the insect (*e.g.*, alfalfa, seed beets) is likely to lead to heavy losses, and should, therefore, be avoided.

DISCUSSION

The seed pitting of lima bean and cowpea in California is due to the feeding of Lygus bugs, the toxin secreted apparently causing the death of a considerable number of cells around the puncture. Because symptoms of the Lygus injury in California and Idaho specimens were identical with those of yeast spot of lima bean from Virginia, the difficulty of identification of the trouble solely on the basis of symptoms becomes apparent.

The writers have had no direct experience with the yeast-spot disease of the eastern states and cannot, therefore, evaluate that situation. The published record, however, presents some features which require clarification. It seems possible that the pitting attributed to yeast in certain areas may involve also an effect of insect toxins. Specimens of yeast spot of lima bean from Virginia[3] proved to be identical in appearance with California samples, but microscopic examination and isolation attempts showed that numerous lesions had no *Nematospora,* although it did occur on some seeds. The only tests which have been reported (30) on transmission of the yeast to lima bean by the southern green stinkbug were made by transferring the insects from previously infected bean plants, and no results with uncontaminated bugs have been reported. The possibility seems not to have been excluded that a toxin introduced by the bugs might have caused damage, sometimes augmented by yeast infection. In fact, the reported rapid abscission of flowers and pods is suggestive of such a toxin rather than "the green stinkbug and the disease that accompanies it," as has been suggested (25). This shedding is not attributed by others to the yeast and it seems probable that it results from a toxin introduced by the insect, with or without yeast. Underhill (25) reported injury to lima bean from the direct feeding of the plant bug and infers that this may induce blossom fall. That blossom and pod fall result from Lygus feeding is clearly established (5, 20, 23) and the injury to lima beans in California is typical.

Several investigators (6, 8, 16, 27, 30, and others) have been unable to recover *Nematospora* from plant bugs supposedly carrying it. A few (7, 14, 15) succeeded in recovering the yeast from the bugs and found that transmission was purely mechanical, the insect placing the pathogen in a favorable substrate. The apparent difficulty of recovering the fungus from the insect, and the fact that not all lesions of lima bean, even in yeast spot regions, contain *Nematospora,* suggest that the yeast may be accessory to some other factor, perhaps an insect toxin. Because the southern green stinkbug is prevalent in both Virginia and West Virginia, but rarely carries *Nematospora* in the latter State, Leach and Clulo (14) concluded "that the association of the disease with the stinkbugs is not a constant one, even though the disease may depend upon the insect for inoculation." If no pitting occurs in West Virginia in the absence of the yeast, this might conceivably indicate the absence of toxicogenic strains of the southern green stinkbug or other insect, or might indicate the existence of ecological factors unfavorable to toxin production by them.

Inoculations with the yeast on uninjured lima bean pods were reported to be unsuccessful, but by puncturing the seed with a fine needle infections resulted (29, 30). That the yeast is pathogenic to immature lima bean seed under these conditions is not questioned. The pitting of lima bean in various areas, although similar in symptoms, possibly may result from such different agencies as toxicogenic insects and *Nematospora.* Such a complex

[3] Supplied to W. W. Mackie through the courtesy of Dr. S. A. Wingard.

is not unprecedented. The kernel spot of pecan was attributed first to the feeding of *Nezara viridula* (4, 30), later to the *Nematospora* which they carried (28), and more recently (18) to injury by the bug itself. It is not implied that Lygus bugs are involved in pitting of lima beans in all areas nor that this is the sole insect involved in the injury in California.

SUMMARY

Large and baby lima beans grown in California for dry food, seed, the fresh market, and freezing commonly have a necrotic pitting of the seed which closely resembles the described yeast-spot disease, except for the absence of any pathogen. In one field test 16.10 per cent of the seed was so pitted, with as many as 52 punctures per seed. Similar damage occurs on blackeye cowpea, but has not been observed on common bean in California.

Field and greenhouse tests with Lygus bugs (*L. hesperus, L. elisus,* and perhaps others) caged on lima beans have demonstrated that the pits result from toxic feeding of the insects on the developing fruiting structures. Such Lygus injury and yeast spot cannot be distinguished on the basis of symptoms alone. The situation in other regions having this type of injury of lima bean should be reexamined to evaluate the factors (*e.g.*, insect toxins) of the complex.

The insects also cause, by toxic feeding, a shedding of blossoms and of pods up to 2 inches long; this effect usually produces the most important loss from the bugs in California, amounting in small areas to the total crop. Reduction of grade and the cost of hand sorting of the beans also result from the seed pitting. There is some shriveling of young seed from Lygus feeding, but other undetermined factors appear to be even more important in causing this damage. Reduction of Lygus injury by one application of DDT dust resulted in significant increases in number of green and dry pods, number and weight of beans, and percentage of unpitted seeds. There was a decrease of dry plant weight exclusive of pods, but this was essentially balanced by the increased dry pod weight.

Injury tends to be worst in fields adjacent to established, perennial, favored hosts of the insect, such as seed beets and alfalfa. In some areas the insects may be present for a relatively short time on lima beans, injuring only a small part of the field and part of the pod set; in other areas the bugs remain active on the limas throughout much of the season, injuring most of the pods in whole fields.

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BUD, BLOSSOM, AND POD DROP OF CANNING STRING BEANS REDUCED BY PLANT HORMONES[1]

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INTRODUCTION

A reduction in yield of canning string beans in northwestern Wisconsin has been experienced in recent years because of excessive drop of buds, blossoms, and small beans. Such losses have been greater in some years than in others.

Two factors have appeared associated with this blossom drop, *i.e.*, (1) hot, dry weather and (2) insects. Tarnished plant bugs, *Lygus oblineatus* (Say), and potato leafhoppers, *Empoasca fabae* (Harris), were present in sufficiently abundant numbers to warrant some control measure.

Insecticides have been used in the past to control both plant bugs and leafhoppers. Since Osborn (9) reported the use of pyrethrum to control the potato leafhopper, this insecticide has been used extensively. Recently pyrethrum and derris dusts appeared effective (10) in control of the tarnished plant bug.

Plant hormones, especially α-naphthalene acetic acid, which prevents the formation of abscission layers causing pre-harvest drop of apples (5, 6), seemed promising for preventing drop of blossoms and small beans. No reports have been found where such substances have been used for counteracting insect injury to plants.

This paper presents the results of studies with plant hormones (1) to prevent drop of blossoms and small beans caused by insects or by weather and thus (2) to increase the yield of string beans. Preliminary reports (1, 2) have appeared earlier.

MATERIALS AND METHODS

Greenhouse Trials. In the greenhouse, Brittle (Round Pod Kidney) Bush Wax bean seeds were germinated in moist sand. When the primary leaves had begun to unfold, the vigorous healthy plants were transplanted individually into 6-inch pots containing a mixture of 1 part sand to 2 parts compost. In some cases the plants were used when they had their first trifoliate leaves but not their second, while in others, the plants were beginning to blossom or were in full blossom with small beans.

The plant hormones are designated in tables of results by the following abbreviations. These hormones were prepared in dusts containing from

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The figures were prepared by Eugene Herrling. The statistical analysis was made by James H. Torrie and Virginia Beal.

10 to 640 p.p.m. (parts per million) by mixing the chemically pure substances with Pyrax ABB:[2]

2B3NB = 2-bromo-3-nitro benzoic acid
2C5NB = 2-chloro-5-nitro benzoic acid
PClP = p-chlorophenoxy acetic acid
DPA = 2,4-dichlorophenoxy acetic acid
DPB = α-(2,4-dichlorophenoxy)-*n*-butyric acid
IA = indole-3-acetic acid
IB = (indole-3)-*n*-butyric acid
LA = levulinic acid
NA = α-naphthalene acetic acid
BNA = β-naphthoxy acetic acid
ANA = α-naphthyl acetamide
PA = phenoxy acetamide
PAA = phenoxy acetic acid
P = Pyrax ABB
TIB = 2,3,5-triiodobenzoic acid

The various concentrations of specific hormones were made from an initially prepared stock concentrate. From this, desired dilutions were prepared by adding Pyrax and further mixing in a ball mill.

A plant was dusted by placing it in a cylindrical chamber with a capacity of about 82 liters. A one-half gram sample of dust was expelled directly downward on the plant by compressed air, at 18 to 20 pounds' pressure, through a dust gun (3). The plant was exposed to the cloud of dust in the chamber for 90 seconds. Pyrax was used to dust check plants.

Since illuminating gas causes abscission of plant parts (4), it was employed in a partially gas-filled chamber to induce abscission of bean leaves and petioles. Whatever may be the relation between gas and insect feeding, both stimulate the formation of abscission layers. With gas one can easily regulate the incidence of dropping of leaves, buds, and pods. Thus it provided an easy technique for eliminating the less promising chemicals.

The illuminating gas used had the following components: illuminants (ethylene, propylene, and other hydrocarbon fractions), 8.8; carbon dioxide, 2.6; carbon monoxide, 31.6; hydrogen, 41.3; methane, 9.2; ethane, 1.0; nitrogen, 5.0; and oxygen, 0.5 per cent.

With gas treatment experiments, individually potted plants were employed when the first trifoliate leaves were well developed, but the second ones were not. A series of 6 or 8 plants was dusted. Best results were obtained when the soil about the plants was kept moderately moist. Excessive moisture or dryness was unfavorable for duplication of results. Watering immediately before the test provided a source of error.

Fifteen to 20 minutes after the plants had been dusted, they were placed

[2] Pyrax ABB is the symbol used to designate an inert material commonly employed in preparing insecticidal dusts.

in a circle inside a double glass-walled temperature chamber with a capacity of about 465 liters and a temperature of 84° to 86° F. A flask was filled by water displacement with about 3.45 liters of illuminating gas, and it was opened in the middle of the chamber. A small electric fan running slowly circulated the gas and air mixture of about 1 : 135. This concentration was hardly enough to have an odor.

All plants were removed from the gas chamber to the greenhouse after 24 to 26 hours. For a week readings were made of the number of abscissions of the various parts of each plant. Seven abscissions were possible in each plant; *i.e.*, the 2 primary leaf blades, the 2 petioles of the primary leaves, and each of the 3 leaflets of the first trifoliate.

Abscission by insects was induced by caging adult tarnished plant bugs on bean plants, which either were beginning to blossom or were in full blossom with small beans. Cages varied in type, including screen cages with a capacity of 425 and 100 liters, respectively, in which were placed dusted, potted bean plants infested with insects. Other small screen cylinders (20 by 40 mm.) confined the insects on plant parts, such as blossoms, beans, and portions of stems bearing flower clusters. Either cotton or Scotch tape was used to enclose the ends. Small paper sacks were also used.

Field Tests in 1942. In the field the problem of blossom and bean drop of canning beans was studied during the summer of 1942. The experimental plots located at Earl and Cumberland, Wisconsin, were planted to Brittle (Round Pod Kidney) Bush Wax beans and Idaho Refugee Bush Green beans, respectively.

Plots at both locations were identical, with separate dust and spray plots at each. All treatments were placed by chance in each of 4 replications. One treatment in each replicate consisted of four 15-foot rows of beans, making a total of 240 feet of row. A single buffer row was left between each unit, and a 2-foot buffer space separated the ends of units.

The following materials were employed in the dust and spray formulae: A commercial preparation (App-L-Set) containing 16 grams of α-naphthalene acetic acid per pound of talc was used in dusts. A commercial preparation (Parmone) containing 16 grams of α-naphthalene acetic acid per pint of alcoholic solvent was used in sprays. Powdered cubé insecticide containing 4.6 per cent rotenone was employed in dusts and sprays. Powdered pyrethrum insecticide containing 2 per cent pyrethrins was used in dusts and sprays. A spreading agent (Grasselli) was used in sprays. Pyrax ABB was the diluent for the dusts.

From these materials, the following were prepared: Dusts—α-naphthalene acetic acid, 140 p.p.m. and 70 p.p.m.; and α-naphthalene acetic acid, 140 p.p.m., plus pyrethrins 0.2 per cent and 0.5 per cent rotenone. Sprays—α-naphthalene acetic acid, $7\frac{1}{2}$ p.p.m., 5 p.p.m., and $2\frac{1}{2}$ p.p.m.; and α-naphthalene acetic acid, 5 p.p.m., plus pyrethrins 0.2 per cent and 0.5 per cent rotenone.

The dusts were applied with a hand-operated rotary-type duster with

2 outlets directed upon 1 row. The sprayer was a Hudson barrel type with which a pressure of about 125 pounds was maintained. Two nozzles were directed on a single row. Dusts were applied at approximately 30 pounds per acre, and sprays were applied at about 100 gallons per acre.

Two applications of dusts and sprays were made to all the plots of beans. The first application to wax beans was made July 17 between 7 and 9 p.m., at which time there was no wind. It was very humid, and the temperature was 85° F. Lower blossoms on the plants were well opened, and buds on upper stems were closed but well developed. A heavy rain fell 24 hours after application. A second application was made July 24 between 7 and 9 p.m. It was rather humid, there was very little wind, and the temperature was 72° F. Small beans and well-developed blossoms were on the plants. Rain fell 8 hours after application.

Since Refugee is a later variety, dust and spray applications were made later in the season. The first application was made July 22 between 11 a.m. and 1 p.m. It was rather humid, there was a light wind, and the temperature was 70° F. About one-half of the blossoms was fully developed. Rain fell 6 hours after application. A second application was made July 30 between 7 and 9 p.m. Weather conditions were the same as for the first application. Small beans and well-developed blossoms were on the plants.

Five pickings of beans were made from each plot. To attain more uniformity in picking, each of four pickers harvested one replication of each treatment and check. The yield from each replicate was placed in separate bags, labeled, weighed, and graded by a mechanical grader.[3]

Some studies were made to determine the extent of damage caused by the tarnished plant bug and the potato leafhopper on wax bean plants. Observations were made of injury caused by these insects on plants dusted with α-naphthalene acetic acid at 70 p.p.m. as compared with insect-infested undusted plants. Wire cages of about 100 liters space confined the insects on the bean plants.

Field Tests in 1943. Five hormones, which had appeared best in the gas chamber trials, were chosen for field tests. Pyrax ABB was used as the dispersing agent for the hormone dusts.

Dusts for wax beans were employed at concentrations of 40, 80, and 160 p.p.m. with each of 4 hormones, *i.e.*, α-naphthalene acetic acid, levulinic acid, p-chlorophenoxy acetic acid, and 2,3,5-triiodobenzoic acid. At 20, 40, and 80 p.p.m. alone, 2,4-dichlorophenoxy acetic acid was used, and at these same concentrations containing 0.2 per cent pyrethrins and 0.5 per cent rotenone. Another dust contained only 0.2 per cent pyrethrins and 0.5 per cent rotenone.

Since α-naphthalene acetic acid did not appear effective on Refugee green beans in 1942, it was decided to try 2,4-dichlorophenoxy acetic acid at 20, 40, and 80 p.p.m. To similar preparations, 0.2 per cent pyrethrins and 0.5 per cent rotenone were added. A formula containing only 0.2 per cent pyrethrins and 0.5 per cent rotenone was also employed.

[3] Located at the Stokely Canning Factory, Cumberland, Wisconsin.

Sprays for wax beans were employed at concentrations of 40, 80, and 160 p.p.m. of α-naphthalene acetic acid alone, and with 0.2 per cent pyrethrins and 0.5 per cent rotenone.

Wax bean dust plots, one each at Earl and Rice Lake, Wisconsin, consisted of 72 units with suitable buffers. Each unit consisted of 4 rows of beans, each row being 17 feet long. Each plot involved 20 treatments, replicated 3 times, and 12 checks.

Refugee green beans were dusted at Earl in a plot having the same arrangement as the spray plots there.

Wax bean spray plots were located at Earl and Rice Lake, Wisconsin.

TABLE 1.—*Summary of conditions when the field treatments were made in 1943*

Place, kind of bean, treatment, date	Applications made between	Weather[a]			Bean plant development
		Dew	Wind	Temperature range	
	A.M.			°F.	
Earl, Wis.					
Wax beans					
Dust plot					
July 18	6:30–9:00	Heavy	None	60–80	Blossoms
28	6:30–9:00	Heavy	None	68–80	First picking completed
Spray plot					
July 19	10:00–12:00	Heavy	Light	82–82	Blossoms
27	8:00–10:00	Heavy	Light	80–80	Ready for first picking
Refugee beans					
Dust plot					
Aug. 1	9:00–10:00	Moderate	Light	84–84	Blossoms
8	6:00–8:00	Heavy	None	68–70	Blossoms and 1-inch beans
Rice Lake, Wis.					
Wax beans					
Dust plot					
Aug. 1	6:00–8:00	Heavy	None	68–68	Blossoms
7	6:00–8:00	Heavy	None	68–68	Blossoms and 3-inch beans
Spray plot					
July 30	10:00–12:00	None	Light	82–82	Blossoms
Aug. 7	10:00–12:00	None	Light	80–80	Blossoms and 3-inch beans

[a] There was no rain for several days after any treatment.

They consisted of 48 blocks equivalent in size to those of the dusted plots. Each treatment, as well as the untreated check, was replicated 6 times.

Demonstration plots were dusted on July 18 and 28, 1943, at Earl, Wisconsin, and on July 20 and 29, 1943, at Barron, Wisconsin. A dust composed of α-naphthalene acetic acid at 80 p.p.m. was applied to three 100-foot rows of beans. Parallel to these treated rows were 3 untreated rows of the same length.

Methods and equipment used in dusting, spraying, and recording yields and grades of the various treated and untreated beans were the same as employed in 1942.

A summary is presented in table 1 of the weather conditions at the time of the application of the dusts and sprays in the replicated plots.

Studies were made of damage to wax beans by the tarnished plant bug, the potato leafhopper, and the six-spotted leafhopper, *Macrosteles divisus* (Uhler). Trials were also made to prevent insect damage by dusting plants with α-naphthalene acetic acid at 80 p.p.m. Cages of about 100 liters capacity were used to retain insects of a particular species on the bean plants for observations.

EXPERIMENTAL RESULTS

Hormones Tested Against Gas-Induced Abscissions. Numerous exploratory trials were made with α-naphthalene acetic acid dusted on wax bean plants. Various constant temperatures and concentrations of illuminating

TABLE 2.—*Summary of evaluations by gas treatment of several plant hormones for prevention of abscission layer formation*

Hormones	Average abscissions[a] per plant from			Abscissions with hormones compared to those with Pyrax[b]	
	Hormones at 20 p.p.m.	Pyrax	Parallel NA at 10 p.p.m.	Hormones at 20 p.p.m.	Parallel NA at 10 p.p.m.
	No.	*No.*	*No.*	*Per cent*	*Per cent*
DPA	0.2	4.7	0.0	5	0
PClP	2.7	6.2	1.5	44	24
DPB	1.5	3.0	0.0	50	0
LA	2.7	4.7	0.2	58	5
2C5NB	1.7	3.0	0.0	58	0
ANA	2.2	3.0	0.0	75	0
IB	4.5	5.7	0.7	78	13
PA	4.0	4.7	0.2	84	5
IA	5.0	5.7	0.7	87	13
TIB	5.7	6.2	1.5	92	24
BNA	6.0	6.5	4.0	92	61
2B3NB	3.2	3.0	0.0	108	0
PAA	5.2	4.7	0.0	111	0

[a] Seven abscissions were possible on each plant.
[b] Secured from dividing the number of abscissions with the hormone by those with Pyrax.

gas were used. It was found that a dust of α-naphthalene acetic acid at 10 p.p.m. with Pyrax prevented a great deal of abscission of the bean leaves and petioles after exposure for a day at 84° to 86° F. in 1 part of gas to 135 parts of air.

Comparisons of relative efficiency of these hormones in preventing abscissions were based on the use of Pyrax alone, α-naphthalene acetic acid at 10 p.p.m., and 2 other hormones at 20 p.p.m. Each experiment, performed twice, employed 8 plants, 2 for each of the 4 dusts to be used.

When the number of abscissions was recorded, notes were taken also of epinasty that developed in leaves and leaflets. Occasionally epinasty was only temporary. However, it was pronounced in those cases where abscission followed. Figure 1, A, shows successive stages of epinasty followed by abscission of the primary leaves.

The data presented in table 2, where both trials are averaged, indicate

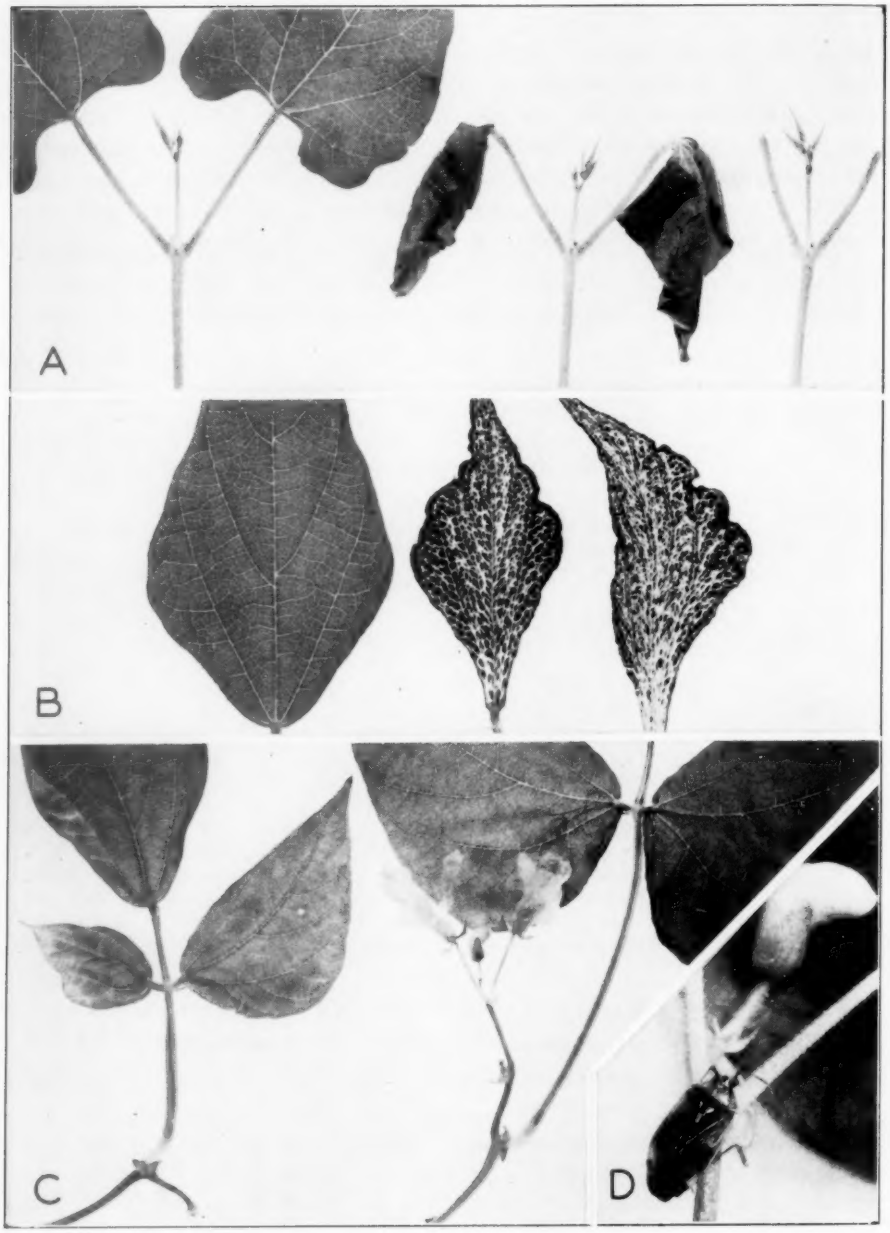

FIG. 1. Effects of illuminating gas, alpha-naphthalene acetic acid, and insects on kidney wax beans. A. Successive stages in leaf drop induced by illuminating gas. B. Left, untreated leaflet. Center and right, symptoms resembling mosaic induced by the hormone in dust form at 640 p.p.m. C. Left, *Lygus oblineatus* has damaged untreated leaflets and has induced blossom drop. Right, blossom drop was prevented with the hormone at 80 p.p.m. D. *L. oblineatus* feeding on pedicels. Approximately × 2.

that α-naphthalene acetic acid (NA) at 10 p.p.m. is superior to the other hormones used at 20 p.p.m., except 2,4-dichlorophenoxy acetic acid (DPA). Among the materials tested, α-naphthalene acetic acid and 2,4-dichloro-

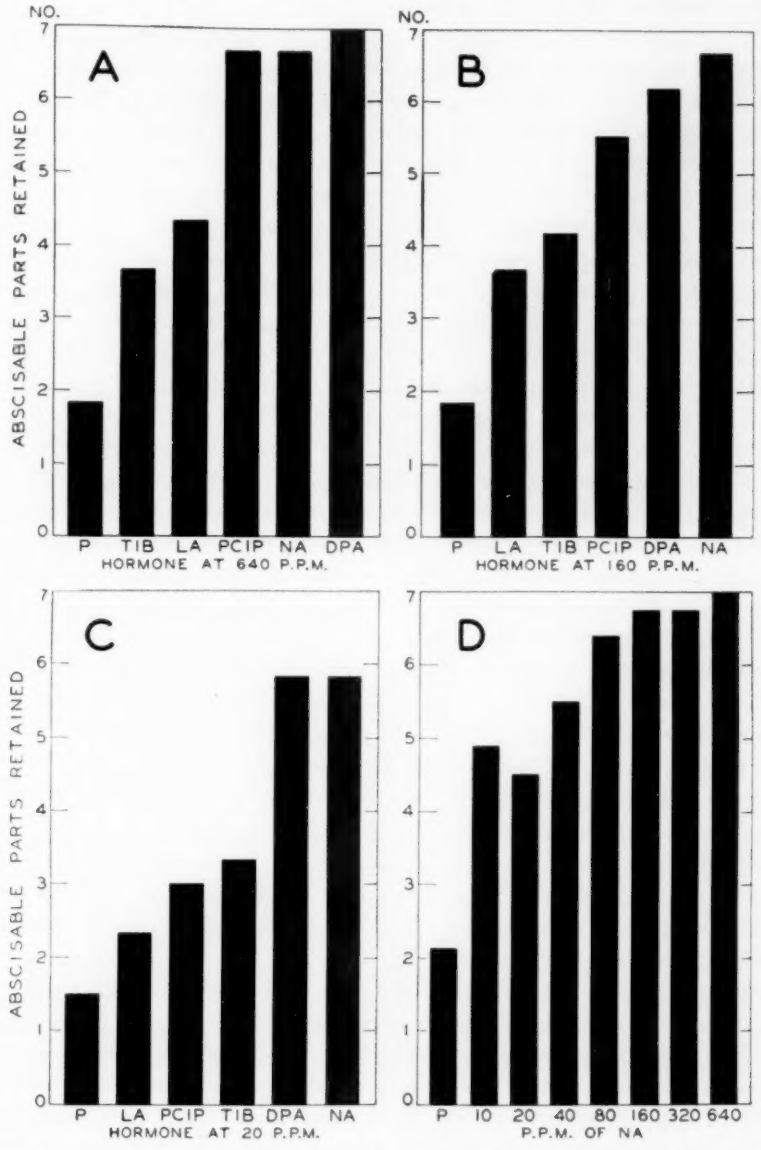

FIG. 2. Summary of retention of abscissable parts by bean plants after treatments, both with gas and with hormones of different kinds at various concentrations. Abbreviations are explained in the text.

phenoxy acetic acid were effective, while p-chlorophenoxy acetic acid (PClP) and levulinic acid (LA) were moderately effective in preventing abscissions. Each of these materials and triiodobenzoic acid were then prepared in dusts

at 20, 160, and 640 p.p.m. Although data presented in table 2 show triiodobenzoic acid to be poor, it seemed worth testing at higher concentrations, because it was not a finely divided crystalline material, and thus may not have been mixed well at a low concentration.

Three experiments were made to compare the 5 hormones at the 3 specific concentrations designated. In each experiment there were 6 plants, 5 for comparison of hormones at one concentration, and 1 Pyrax check. Six replications of each experiment were made, and a change in position of the various treatments within the chamber was made for each successive replication. No evidence, however, indicated that such change in position was necessary.

Table 3 shows a comparison of the abscission-prevention qualities of hormones at 640 p.p.m. Similar tables could be shown for the other 2 experiments, with the hormones at 160 p.p.m. and 20 p.p.m., but the data of all three are expressed graphically in figure 2, A, B, and C, which show the average number of abscissable parts retained by the plants. In the hormone comparisons at 160 p.p.m., the M.S.D. (minimum significant difference) at the 5 per cent level was 1.35 (mean), and 1.84 (mean) at the 1 per cent level. In the 20 p.p.m. comparisons, the M.S.D. was 1.33 (mean) at the 5 per cent level, and 1.82 (mean) at the 1 per cent level. All 5 hormones gave significant results at the 5 per cent level when used at concentrations of 640 and 160 p.p.m. At 20 p.p.m., only levulinic acid results were not considered significant. Most significant results were obtained with α-naphthalene acetic acid and 2,4-dichlorophenoxy acetic acid.

To obtain information as to the effectiveness of α-naphthalene acetic acid at several strengths in dust form, concentrations of 10, 20, 40, 80, 160, 320, and 640 p.p.m. were tested. Each of 7 bean plants was dusted with a different concentration of the hormone, and another plant was dusted with Pyrax to serve as a check. This group of 8 plants was subjected to gas in the chamber. The procedure was replicated 8 times, and a change in position of the various treatments within the chamber was made for each successive replication.

Figure 2, D, which indicates the average number of abscisable parts retained by plants, shows the ability of several α-naphthalene acetic acid concentrations to prevent abscission.

During the preceding experiments, it was observed that the higher concentrations of α-naphthalene acetic acid and 2,4-dichlorophenoxy acetic acid caused virus-like symptoms of vein-clearing, distortion, and dwarfing of bean plant leaflets. Since these observations were of plants which had been placed in the gas chamber, tests were made to produce such symptoms, if possible, on hormone-dusted plants permitted to grow in the greenhouse without being subjected to the gas chamber.

Each of 16 wax bean plants containing a single trifoliate was dusted with a $\frac{1}{2}$-gram sample of dust. Two plants received either α-naphthalene acetic acid at 10, 20, 40, 80, 160, 320, 640 p.p.m. or Pyrax. After treatment these plants were permitted to grow until all had trifoliates, at which stage observations were made for possible damage.

Plants dusted with α-naphthalene acetic acid at 640 p.p.m. showed vein-clearing, distortion, dwarfing, and a darker green color of the leaflets of the third to seventh, inclusive, trifoliates on 1 plant and third to eighth, inclusive, on the other (Fig. 1, B). The plants dusted with the 320 p.p.m. concentration were similarly, though slightly less, affected on the third to fifth, inclusive, trifoliates on 1 plant and fourth to eighth, inclusive, on the other. The 160 p.p.m. concentration produced a slight tendency toward these symptoms in the third to sixth, inclusive, trifoliates. The other concentrations of the hormone and Pyrax did not cause these symptoms.

Parallel experiments with 2,4-dichlorophenoxy acetic acid produced symptoms similar to those obtained with α-naphthalene acetic acid when the former was used at 640 and 320 p.p.m., but the 160 p.p.m. concentration did not produce the symptoms.

TABLE 3.—*Comparison of abscission-prevention qualities of five hormones at 640 p.p.m.*

Replicates	Abscissions					
	P	NA 640	LA 640	DPA 640	PCIP 640	TIB 640
1	5	0	3	0	2	6
2	4	2	1	0	0	4
3	5	0	4	0	0	5
4	4	0	0	0	0	2
5	6	0	4	0	0	1
6	7	0	4	0	0	2
Total	31	2	16	0	2	20
Average[a]	5.17	0.33	2.67	0.0	0.33	3.33

[a] M.S.D. at 5 per cent level—1.50 (mean); at 1 per cent level—2.05 (mean).

Symptoms similar to those produced on wax beans occurred on Henderson Bush Lima beans when they were dusted with α-naphthalene acetic acid at the same concentrations. Each plant had developed 2 trifoliate leaves at the time of dusting. The 640 p.p.m. hormone dust produced the symptoms on the succeeding 5 trifoliates of 1 plant, and on 6 of another. Slightly less evident were these symptoms on the succeeding 2 and 3 trifoliates of 2 plants dusted with the 320 p.p.m. concentration.

The tests show that these symptoms move upward into the developing trifoliates. These virus-like symptoms were similar to those reported by Zimmerman and Hitchcock (11), and doubtless were caused by the hormone and not by a virus. Limited trials on virus transmission were negative. In all of the experimental work carried out, no bean plants were employed which developed mosaic. Scarcely any of the plants grown for testing showed mosaic symptoms and in these occasional appearances none resembled the hormone effects.

Insect-induced Abscissions Prevented by Hormones. During the first week of July, 1942, a survey of canning bean plantings was made in Barron, Burnett, Polk, Rusk, Sawyer, and Washburn Counties of Wisconsin to deter-

mine the insect species most abundant on string beans. Species most noticeable were: potato leafhopper, *Empoasca fabae* (Harris)—six-spotted leafhopper, *Macrosteles divisus* (Uhler)—tarnished plant bug, *Lygus oblineatus* (Say)—rapid plant bug, *Adelphocoris rapidus* (Say)—alfalfa plant bug, *Adelphocoris lineolatus* (Goeze)—potato flea beetle, *Epitrix cucumeris*

TABLE 4.—*Field and greenhouse trials with feeding by insects on entire plants in full bloom, and hormone treatments in relation to beans produced*

Date	Insects			Plants	Concentration NA	Total beans produced
	Species	Population	Feeding[a] time			
		No.	*Days*	*No.*	*P.p.m.*	*No.*
Field trials						
July 15, '42	*Lygus oblineatus*	12	37	3	70	9
	do	12	37	3	0	7
	Empoasca fabae	30	37	3	70	12
	do	30	37	3	0	12
	None	0	.....	3	0	15
July 12, '43	*L. oblineatus*	18	25	3	80	10
	do	18	25	3	80	9
	do	18	25	3	0	8
	E. fabae	40	25	3	80	12
	do	40	25	3	80	13
	do	40	25	3	0	13
	Macrosteles divisus	40	25	3	80	16
	do	40	25	3	80	16
	do	40	25	3	0	16
	None	0	.....	3	0	14
	do	0	.....	3	0	17
Greenhouse trials						
May 5, '43	*L. oblineatus*[b]	17	25	3	10	8
	do		25	3	0	6
	None	0	.....	3	0	11
Nov. 30, '43	*L. oblineatus*	30	29	2	80	4
	do		29	2	0	1
	None	0	.....	2	0	11
Oct. 11, '44	*L. oblineatus*	55	4	4	80	12
	do		4	4	0	10
	do	55	4	4	80	10
	do		4	4	0	7
	None	0	.....	4	0	20
Nov. 18, '44	*L. oblineatus*	15	2	2	160	4
	do		2	2	0	4
Nov. 23, '44	*L. oblineatus*	45	8	3	80	7
	do		8	3	0	4

[a] Insects could feed on the entire aerial parts of the plants.

[b] The 17 insects were free to feed on all 6 plants. The brackets indicate a similar situation in other trials.

(Harris)—striped flea beetle, *Systena taeniata* (Say)—spinach flea beetle, *Disonycha xanthomelaena* (Dalman)—spotted cucumber beetle, *Diabrotica duodecimpunctata* (F.)—striped cucumber beetle, *Diabrotica vittata* (F.)—bean leaf beetle, *Ceratoma trifurcata* (Forst.)—bean aphid, *Aphis rumicis* L.—leafhopper, *Polyamia inimicus* (Say).

The first 5 species were the most prevalent. They feed by sucking plant

juices, and the damage is usually not noticeable until considerable injury has been accomplished. The feeding of some plant bugs (Miridae) has been associated particularly with the blasting of blossoms. Such insects, especially the tarnished plant bug, rapid plant bug, and alfalfa plant bug, were usually found feeding on or near the blossoms and small beans (Fig. 1, D). The effect of such feeding appears in figure 1, C, where the plant at the left has lost buds and blossoms and has small and more or less distorted leaves in comparison with the hormone-dusted plant at the right.

To ascertain injury to wax bean plants caused by the 3 most abundant insects inhabiting the bean foliage in the field, *viz.*, potato leafhopper, six-spotted leafhopper, and tarnished plant bug, these insects were collected according to species and caged on healthy plants in the field and greenhouse. Incorporated in the trials were plants dusted with α-naphthalene acetic acid. Specific insects were caged also on these plants to determine if the hormone might control insect damage. Wire cages with a capacity of 100 liters were used in the field; and in the greenhouse, wire cages with a capacity of 425 liters.

Table 4 presents the data secured from field and greenhouse trials relating to reduced bean yields caused by some insects and the prevention of some of the damage by hormone dust treatments of the plants. Very few of the insects were alive at the end of the longer feeding periods.

These insect studies on entire plants indicated that *Macrosteles divisus* had no detrimental effect, that *Empoasca fabae* had some aside from hopperburn, and that *Lygus oblineatus* had considerable. This effect of *L. oblineatus* appeared (Fig. 1, C) on the leaflets as reduction in size, wrinkling, and mottling. It appeared on the fruiting parts either as bud, blossom, or pod drop, or as malformation of pods retained, with resulting reduction in yield. Some of this damage was reduced by dusting the bean plants with α-naphthalene acetic acid.

To determine results of insect feeding in localized areas of the plants, small numbers of tarnished plant bugs were caged on wax bean blossom clusters by means of a small paper bag, or were caged on a stem from 1 to 2 inches below the basal attachments of blossom pedicels. At 24 to 48 hours preceding the placement of insects, some of the bean plants were dusted with α-naphthalene acetic acid and the others with Pyrax. After varying lengths of time, the insects were removed, and the ultimate production of mature beans was recorded. Reference is made to these trials in table 5.

The feeding of the tarnished plant bugs on wax bean blossoms will cause the blossoms and small beans to blast, thus a reduced yield of beans. This insect may also cause blossom and small bean blasting, and a resultant reduced yield by feeding on that part of a stem between 1 and 2 inches below the basal attachment of pedicels bearing blossoms. Bean plants were dusted with α-naphthalene acetic acid before these insects were allowed to feed, and the reduction in yield was not so great as with those untreated. Beans from untreated plants were more apt to be malformed and small.

TABLE 5.—*Greenhouse trials with feeding by a population of three Lygus oblineatus on flower parts, and hormone treatments in relation to beans produced*

Date, 1944	Feeding time	Bean plants		Concentration NA	Beans produced
		Blossoms	Plants		
	Hrs.	*No.*	*No.*	*P.p.m.*	*No.*
Insects feeding on blossoms[a]					
Nov. 16	27	6	2	160	2
	27	6	2	0	1
Nov. 16	75	9	3	80	5
	75	9	3	0	2
Nov. 23	120	9	3	80	3
	120	9	3	0	2
Insects feeding on stems[b]					
Nov. 20	144	6	2	80	3
	144	6	2	0	1
Nov. 24	96	9	3	80	4
	96	9	3	0	2
Nov. 25	120	9	3	80	3
	120	9	3	0	1

[a] Entire blossom cluster containing 3 blossoms.
[b] Stem supporting 3 pedicels, each bearing 1 blossom.

Bean Yields Increased in 1942 by Hormones. Yields of beans following application of α-naphthalene acetic acid dust at 140 p.p.m. in 1942 (see 1 and 2) are shown in detail in table 6 as an example of the procedure. The treated plants had an increase in yields of 18.4 per cent over the untreated. This figure is designated as + 18 in summary table 7, where the results appear from different concentrations and combinations, from two varieties, and from two methods of application. Applications to Round Pod Kidney Wax Beans of α-naphthalene acetic acid as a dust at either 70 or at 140 p.p.m. with

TABLE 6.—*Yields of Wax beans from representative hormone-treated and untreated blocks at Earl, Wisconsin, in 1942*

Treatment and picking date	Yield in replicates				Total yields
	1	2	3	4	
	Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*
Dust treatment—NA 140 p.p.m.					
July 31	100	128	112	140	480
Aug. 6	168	176	164	196	704
Aug. 11	64	56	44	64	228
Aug. 17	64	48	48	40	200
Aug. 21	24	12	12	12	60
Total	420	420	380	452	1672[a]
No treatment (controls)					
July 31	92	88	84	68	332
Aug. 6	124	176	168	144	612
Aug. 11	64	52	52	40	208
Aug. 17	56	52	40	52	200
Aug. 21	20	16	12	12	60
Total	356	384	356	316	1412

[a] 18 per cent increase over untreated.

insecticides, respectively, gave increased yields of 17.8 and 15.6 per cent, which appear as 18 and 16 per cent in table 7. The addition of pyrethrum and cubé to the hormone dust at strengths employed did not significantly influence the yield, probably because they did not adequately control insects. None of the sprays was significantly beneficial, and some were harmful, possibly because the force of the spray knocked off some blossoms, and because the hormone was not present in a suitable form. Murneek, Wittwer, and Hemphill (8) have reported beneficial as well as detrimental results from spraying snap beans with hormones. As explained earlier, the strength of the treatments was rapidly reduced in every case by rains that came some hours after the treatment.

It is possible that α-naphthalene acetic acid may be specific for various bean varieties, similar to its varietal specificity in preventing pre-harvest

TABLE 7.—*Total yields of beans expressed in percentage increase or decrease over check from the dust and spray plots of Wax and Refugee beans*

Treatments	Percentage increase or decrease over check[a]	
	Wax beans	Refugee beans
Dusts		
(NA 140 p.p.m.)	+18	+ 8
(NA 70 p.p.m.)	+18	+ 9
(NA 140 p.p.m., pyrethrins 0.2 per cent + rotenone 0.5 per cent)	+16	+ 3
Sprays		
(NA 7½ p.p.m.)	+ 3	− 4
(NA 5 p.p.m.)	+ 4	−11
(NA 2½ p.p.m.)	+ 1	+ 7
(NA 5 p.p.m., pyrethrins 0.2 per cent + rotenone 0.5 per cent)	+ 8	0

[a] Untreated controls in Wax bean dust plots yielded 4805 pounds per acre, in Wax spray plots 5064 pounds, in Refugee dust plots 8737 pounds, and in Refugee spray plots 8465 pounds.

apple drop as reported by Hitchcock and Zimmerman (7). This may account for the small increase in yields of hormone-dusted Refugee beans. At the same time these beans are later and may not be subject either to the insects or hot weather that favor blossom drop.

These data did not show whether the increased yield in hormone-dusted plots was due to production of more beans or of larger beans. Consequently, in every case a sample of 100 ounces of beans from each replication of each treatment and from each check after each picking was passed through the canning factory mechanical grader. Records were kept of Grade A and Grade B beans, the former being the smaller, higher-grade beans.

The average percentage of Grade A beans was 51 for the check and 54, 55, and 55 for the respective dust treatments, which employed the hormone and which averaged about a 17 per cent greater yield than the check. Apparently a larger number of small beans occurred in the hormone-treated pick-

ings than in the untreated. It seems clear that the 17 per cent increased yield was due to more beans, rather than to larger beans. As is generally true with many plants, the more units of fruit there are produced, the smaller are the fruits. Smaller beans bring higher prices for canning. Since increased yields came from more beans of smaller size in comparison with the check, it follows that the treated plants retained more blossoms and beans than those untreated.

Bean Yields Increased in 1943 by Hormones. Due to the favorable results obtained with α-naphthalene acetic acid used as dust in 1942, laboratory, as well as field, trials were made in 1943. Employing the information gained from testing abscission-preventing substances under laboratory conditions with illuminating gas, it was possible to arrive at concentrations of

TABLE 8.—*Yields*[a] *in ounces of Wax beans from α-naphthalene acetic acid dust plot at Earl, Wisconsin, in 1943*

Picking date	Beans from plants treated with α-naphthalene acetic acid dust at							
	40 p.p.m.				80 p.p.m.			
	Replicates				Replicates			
	1	2	3	Total	1	2	3	Total
	Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Oz.*
July 27	34	23	39	96	31	32	30	93
Aug. 1	96	108	116	320	113	86	116	315
Aug. 5	40	41	77	158	78	81	63	222
Aug. 9	44	57	77	178	44	57	84	185
Aug. 14	25	17	81	123	25	29	69	123
Aug. 25	49	31	60	140	33	46	34	113
Sept. 9	127	117	80	324	57	70	24	151
Total	415	394	530	1339	381	401	420	1202

[a] Total yield of untreated beans was 1073 ounces. With the hormone at 40 p.p.m., there was a change of +24 per cent, and at 80 p.p.m., +12 per cent, which figures appear with the results at Earl in table 9.

particular plant hormones most desirable for use in field trials. Because of the larger number of materials and concentrations employed, there were only 3 replications in the 1943 field plots.

Yields in ounces of beans picked from the various replicated experimental plots were recorded as before. A part of the detailed data secured is presented in table 8 as an example.

During this season various difficulties appeared for accurate record taking. The larger size of the plots and changing personnel made it impossible to have one picker take an entire replication as in the previous year. This accounts for at least a large part of the increased variability of results over those secured the previous year.

The results of these 1943 trials appear in summary form in table 9. An analysis of variance on the data indicated no significance at the 5 per cent point in the plot at Rice Lake. However, there was significance in results at Earl, and also in results from these 2 plots when taken together, for the

beneficial effect of α-naphthalene acetic acid at 40 p.p.m. and at 80 p.p.m. The detrimental effect of this acid at 160 p.p.m. in dust and at all concentrations in sprays was apparent. None of the other substances appeared particularly good or bad.

The poor showing from the sprays was caused in part by the mechanical damage from the high pressure (125 lb.) which knocked off many blossoms and small beans. This is apparent since the yields from beans sprayed with

TABLE 9.—*Summary of percentage increase (+) or decrease (−) in yields produced by Wax beans treated with hormones in 1943*

Substances used	Amount of hormone used	Results with wax beans at	
		Earl[a]	Rice Lake[a]
	P.p.m.	*Per cent*	*Per cent*
Dusts			
α-Naphthalene acetic acid	40	+24	+14
do	80	+12	+ 8
do	160	−17	− 1
2,4-Dichlorophenoxy acetic acid (No. 1)	20	− 5	− 6
do	40	−13	+ 8
do	80	+ 2	+ 1
2,4-Dichlorophenoxy acetic acid (No. 1) + pyrethrins 0.2 per cent + rotenone 0.5 per cent	20	−10	− 1
do	40	− 4	− 1
do	80	+ 1	− 5
2,4-Dichlorophenoxy acetic acid (No. 2)	40	−11	+ 9
2,3,5-Triiodobenzoic acid	40	− 9	+13
do	80	+10	−10
do	160	− 1	+ 4
p-Chlorophenoxy acetic acid	40	− 5	0
do	80	+ 3	− 3
do	160	+ 7	−10
Levulinic acid	40	+ 6	− 4
do	80	+ 3	+ 4
do	160	−10	+ 1
Pyrethrins 0.2 per cent + rotenone 0.5 per cent	0	+ 3	0
Untreated controls	0	0	0
Sprays			
α-Naphthalene acetic acid	40	−27	−23
do	80	−35	−42
do	160	−62	−60
Pyrethrins 0.2 per cent + rotenone 0.5 per cent	0	−29	−14

[a] Untreated controls in dust plot yielded 3540 pounds per acre at Earl and 5185 pounds per acre at Rice Lake.

pyrethrum and cubé, as well as those from beans sprayed with α-naphthalene acetic acid, were significantly less than from unsprayed beans. As the concentration of α-naphthalene acetic acid in sprays was increased, the yield of beans was decreased. Leaflets of plants sprayed with α-naphthalene acetic acid also showed the appearance of crinkle, curl, and mosaic and thus resembled virus symptoms.

The difference in results secured with α-naphthalene acetic acid at 160 p.p.m. in 1943 and at 140 p.p.m. in 1942 is not particularly surprising. The actual situation was that in every case in 1942 a rain followed the treatment

by some hours, which doubtless either greatly reduced the effective concentration on the plants or prevented it from acting long enough to be very damaging.

The results in demonstration trials, described earlier, appear in table 10 which lists the yields of the Round Pod Kidney Wax Bean plot at Earl, and the No. 2 Sensation Wax Bean plot at Barron, Wisconsin. Since these trials were not replicated, results are not of too much significance except to compare with the results from replicated plots. There was an increased yield of 15 per cent from the treated plants over untreated at Earl, and a 26 per cent increase at Barron.

As in 1942, grade records were kept of the 1943 yields from the specific treatments and checks. The average percentage of Grade A wax beans from the Earl dust plot was 68, 71, 67, and 70 for the NA 40, 80, and 160 p.p.m. treatments and the check, respectively; the Rice Lake Grade A percentages

TABLE 10.—*Yields of Wax beans from demonstrational plots in 1943*

Location near	Treatment	Yields from pickings				Total yields	Yield increase
		1	2	3	4		
		Oz.	*Oz.*	*Oz.*	*Oz.*	*Oz.*	*Per cent*
Earl	NA dust 80 p.p.m.	272	472	240	.....	984	15
	None	224	416	216	.....	854	.....
Barron	NA dust 80 p.p.m.	336	736	512	112	1696	26
	None	288	640	336	80	1344	.....

were 84, 81, 83, and 85 in the respective cases. The slight differences in percentage of Grade A beans are not significant, thus one can only conclude that the sieve size of beans from the various α-naphthalene acetic acid-treated blocks was about the same as from check blocks, and that increases in yields of from 8 to 24 per cent must be due to production of more beans rather than larger beans.

DISCUSSION

The falling of buds, blossoms, and small pods has been a serious problem for some time, not only with beans, but with various other plants. The conspicuous success in the prevention of fall of apples (5) is well known and has pointed the way for continuing studies with other crops.

So far as the writers are aware, this paper presents the first evidence that certain kinds of damage from insects can be counteracted by hormones.

Among the difficulties with these lines of work have been (1) the limited season during which blossom drop or related phenomena could be studied out-of-doors and (2) the variability in seasons, which has handicapped quantitative duplication of results. Both have inhibited rapid progress in this important field.

To overcome these difficulties, we have induced the formation of abscission layers rapidly and at will by treatments with illuminating gas. This

technique was used for the first time, as far as we are aware, in our screening tests with various chemicals. It seems to have applications considerably broader than those employed here. However, we do not imply that the formation of abscission layers under the influence (1) of high temperatures and long days, (2) of attacks by certain insects, and (3) of illuminating gas, not to mention natural maturity, are all necessarily identical processes. Nevertheless, the prevention of abscission layers, formed in association with these several influences by α-naphthalene acetic acid, suggests that these processes are at least closely related.

Many comparable problems, such as failure of pod set with lima beans and alfalfa, might be approached with technique similar to that used here. With experiments to repel or to kill certain injurious insects, one might include also materials that would counteract their damaging effect. It might even be pertinent to inquire whether the beneficial effects with apples came entirely from the prevention of abscission layers associated with natural maturity or whether insects might also be helping to hasten the abscission.

The reason for the effectiveness of dusts and the poor results with sprays is rather obscure. Part of the trouble with the sprays came from the excessive pressure employed, which mechanically knocked off some blossoms. In addition, it appears that the hormone came into more intimate contact with the plant, all at once, and then the effect was over soon. Possibly the dust has the advantage of a less vigorous reaction at the time of application and of a longer duration of the effective treatment. Much more hormone can be used in dusts than in sprays. This is fortunate since dusting equipment is more practical for treating this crop.

The advantage is apparent of having a high percentage of the blossoms set on a single stem. For example, a large number of beans will compete against one another and will probably all be in the smaller, high quality, Grade A class. If a smaller number of beans set, they will grow more rapidly between pickings and may easily reach a larger, less desirable, Grade B size.

The strength of application is obviously critical. When the α-naphthalene acetic acid was used at 140 p.p.m., followed by a rain, it was valuable, but the next year when no rain followed, a slightly greater amount (160 p.p.m.) was detrimental. Probably 40 to 80 p.p.m. is better for outdoor application. Much less is effective in a greenhouse where there is little wind.

When too much chemical is applied, various types of injury may be secured, including reduction in yield.

The similarity in activity between the α-naphthalene acetic acid and many other substances, *e.g.*, 2,4-dichlorophenoxy acetic acid, suggests that various other chemicals and other methods of applications are worth investigating.

While we have secured good results with some of these hormone dusts, we recognize the presence of several variables in any commercial bean fields. For this reason the reader will wisely make trials of his own.

SUMMARY

Bud, blossom, and small pod drop of canning beans has reduced the yield in Wisconsin, during hot weather and following attacks by various insects, especially *Lygus oblineatus*. As control measures, various hormones were employed to prevent the formation of abscission layers and subsequent loss.

In laboratory screening tests the formation of abscission layers was induced easily and at will by exposure of the bean plants to illuminating gas, 1 part in 135 parts of air, for about a day at 84° to 86° F. Among the hormones tried, α-naphthalene acetic acid and 2,4-dichlorophenoxy acetic acid were the most promising against abscission layer formation.

When used too strong, these hormones not only prevented the formation of abscission layers, but also induced vein clearing, distortion, and dwarfing of leaflets, which might be confused with virus symptoms. These symptoms commonly appeared in trifoliates developing after treatments, the number being influenced by the concentration.

Lygus oblineatus induced bud, blossom, and small bean drop, and distorted and dwarfed the small leaflets of caged plants in the greenhouse. Some of this loss was prevented by dusting with α-naphthalene acetic acid. Similar results were secured in the field.

About 18 per cent increase in yields of field-grown wax beans was accomplished in 1942 with 2 applications of dust containing α-naphthalene acetic acid at 70 p.p.m. in one case and at 140 p.p.m. in another. Rain followed each application. Dust on Refugee beans and spray on both Refugee and wax beans were not helpful. Sprays were usually detrimental.

More extensive trials in 1943 showed 24 and 12 per cent yield increase, respectively, of wax beans with 2 applications of dusts containing α-naphthalene acetic acid at 40 and 80 p.p.m. but they showed a decrease with dusts at 160 p.p.m. and with sprays. No rain followed these trials. The increase in yield was due to a greater number of small high grade beans rather than to larger beans.

Similar results have been secured in demonstrational plots.

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LESPEDEZA ANTHRACNOSE[1]

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INTRODUCTION

In the autumn of 1941 considerable leaf spotting and defoliation of some volunteer lespedeza plants were observed at Experiment, Georgia. A later survey showed that this leaf spot was widespread in lespedeza fields in Georgia as well as in parts of North and South Carolina. Later the same disease was reported to the writer by Drs. H. W. Johnson and C. L. Lefebvre as having been found in Virginia. Although the disease is rather widespread and seedlings may be stunted or killed during the spring and early summer months and sometimes many leaflets may be lost, stands are never seriously depleted. So far as the writer is aware, this disease has not been reported or described heretofore.

SYMPTOMATOLOGY

The disease is most conspicuous on the leaflets, on which there may be few to many lesions. In nature the number of lesions usually is small; often there are not more than one or a few on a leaflet. The spots vary in diameter from less than one mm. to one-half cm. and often are half the width of the infected leaflet. The lesions usually are somewhat circular or elliptical but may be angular when delimited by veins or at the tips or margins of the leaflets (Fig. 1, A). Any part of the leaflet may be infected, lesions often being found at the apex, along the margins, or on the midrib or other veins. The midrib or smaller veins may be attacked without the surrounding tissue being involved (Fig. 1, B) in which case the lesions are linear with the longer axis parallel to the vein. On the petioles and stems the lesions vary from circular to linear and usually remain small except on the seedlings where the entire diameter of the stem may be involved for some distance (Fig. 1, C, 2, and 3). The lesions, which are apparent on both sides of the leaflet, vary somewhat in color but commonly approach bone brown above and dark olive below (2). At first the surrounding tissue is the normal green, but very soon it becomes pale lemon yellow to apricot yellow and dries to some shade of light brown, often approaching olive-ocher or honey yellow. The margin (Fig. 1, A) may involve half or more of the width of the leaflet; in fact, it may actually involve more of the tissue than the dark area. One lesion often is sufficient to cause the leaflet to drop; and, when many leaflets are affected, considerable defoliation may result. Brownish setae, approaching black under the hand lens, frequently are visible on one or both sides of the lesion. The lesions most commonly originate between the veins but frequently

[1] Cooperative investigations between the Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, and the Georgia Agricultural Experiment Station, Experiment, Georgia. Paper No. 143, Journal Series, Georgia Agricultural Experiment Station.

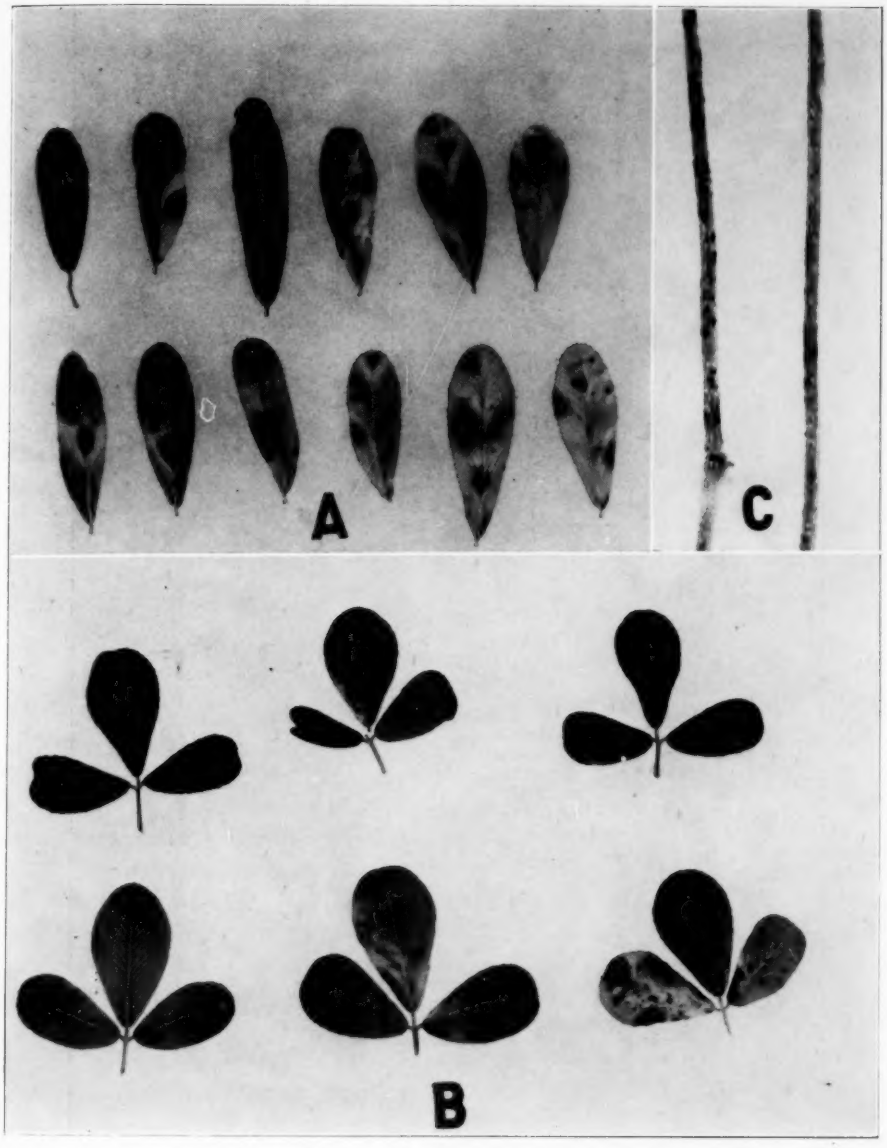

FIG. 1. A. Volunteer annual lespedeza leaflets bearing anthracnose lesions resulting from natural infection. The upper and lower rows of leaflets illustrate the appearance of the lesions on the upper and lower sides of the leaflets, respectively. The midrib may or may not limit the spot. The leaflets that appear light (upper and lower extreme right) were yellowish. ×2. B. Kobe lespedeza leaves with anthracnose lesions resulting from inoculation and 2 healthy control leaves at the left. The upper and lower sides of the leaflets are shown in the upper and lower rows of leaflets, respectively. Photographed 6 days after inoculation. ×1¾. C. Stems of Kobe lespedeza with numerous black anthracnose lesions, resulting from inoculation, somewhat obscured by the very hairy surface. ×2.7.

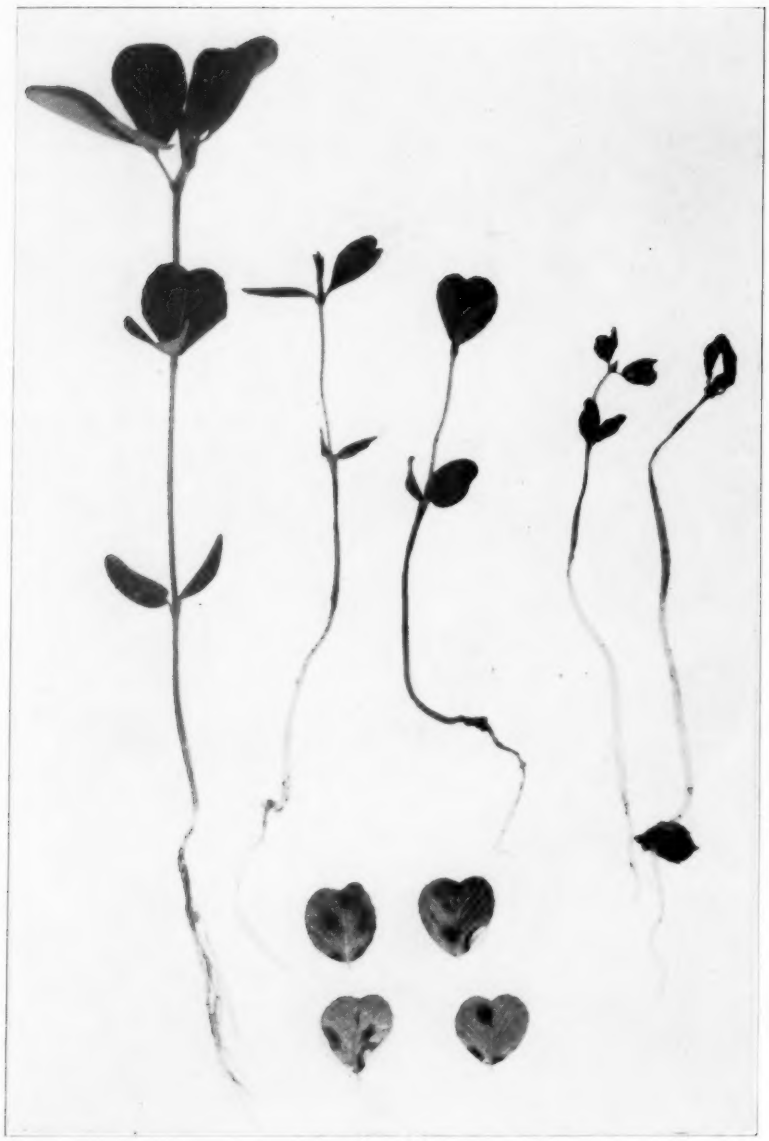

FIG. 2. Kobe lespedeza seedlings. Healthy control at the left, 4 inoculated plants at the right, and 4 inoculated leaflets at the lower center. Photographed 6 days after inoculation. ×1.6.

involve an adjacent vein which then may be slightly more reddish than the remainder of the spot.

ETIOLOGY

Isolations and Inoculations

From lesions on leaflets collected at several places a fungus with the characteristics of a *Colletotrichum* was commonly isolated. The fungus was

studied in pure culture, and inoculations were made to prove its pathogenicity.

The initial isolate formed perithecia sparingly in culture and at first failed to produce conidia. Only a few spores were available, and the first inoculation tests gave negative results. Since the ascospores in culture

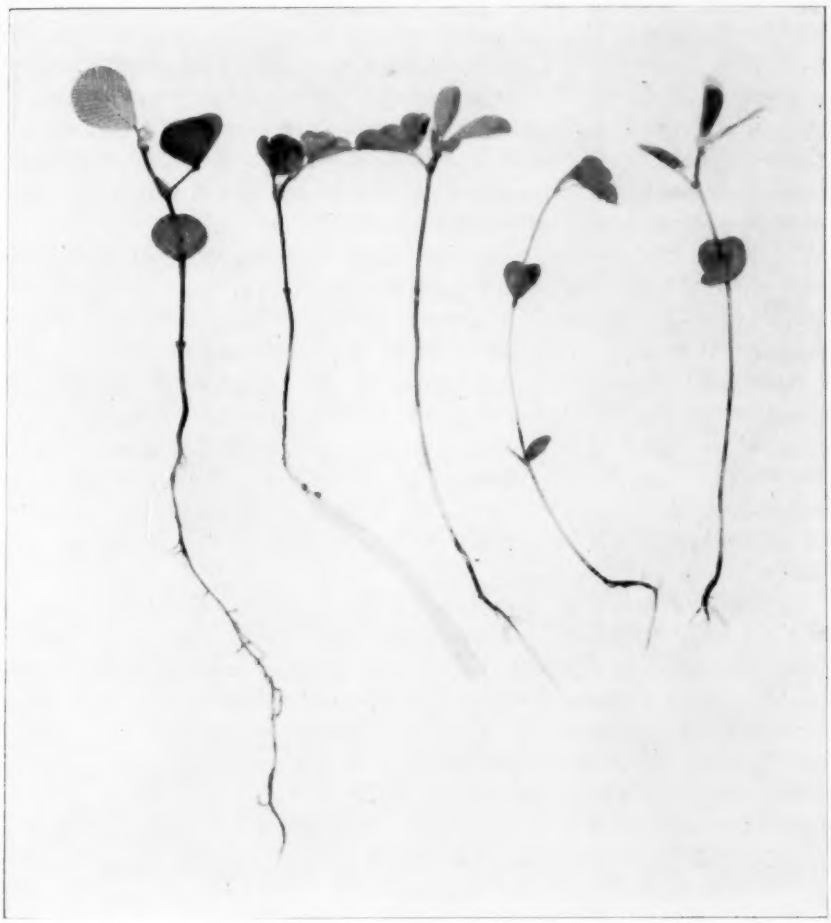

FIG. 3. Naturally infected lespedeza seedlings from an experimental plot. Photographed May 3, 1944. The crowns, some of the larger fibrous roots, the stems, and some leaflets had the characteristic anthracnose lesions. The seedling at the left was about normal size although it had a few small lesions. Note the blackened bases of the stems and the lesions higher up on the stems. The plant at the extreme right has a lesion just below the cotyledonary node and 2 lower down. The next plant at the left has a lesion just above the cotyledons. ×1½.

resembled those of *Glomerella cingulata*, it was thought that if the fungus would decay apple it might be stimulated to a higher state of sporulation. In order to test this supposition two Winesap apples were inoculated. The apples were disinfected for 5 minutes in mercuric chloride (1–1000) and then were washed in sterile tap water and placed in a sterilized moist cham-

ber. Mycelium from a pure line culture was inserted into a wound made in each apple with sterile tweezers. Two other apples were treated in the same manner except that they were inoculated with a culture of *Glomerella cingulata* from apple, and two others serving as controls were disinfected and wounded but not inoculated. The apples were held at room temperature (15° to 24° C.), and the decay progressed slowly. Final observations made after 6 weeks showed that the apples inoculated with the fungus from lespedeza were entirely decayed, whereas those inoculated with the fungus from apple were only about two-thirds decayed. The controls remained healthy. The fungus from lespedeza was recovered from the apple and used for further studies. On the apple it produced acervuli in which conidia were formed in great abundance. Likewise the reisolate sporulated fairly well on corn-meal agar and especially well on sterilized, green-bean pods.

On June 1, 1943, spores from corn-meal agar were atomized onto lespedeza plants about 2 inches tall which then were held in a moist chamber for 48 hours along with comparable noninoculated plants as controls. No infection was apparent for about 72 hours at which time numerous minute brown spots appeared on leaflets and stems. None of the controls was infected. Six days after the inoculations were made leaflets were yellowing and falling, stems had been girdled by typical brownish cankers, and that portion of the plant above the girdle was dying (Fig. 2). As in nature, one spot proved to be sufficient to cause a leaflet to fall. Although stems become more resistant with age, a single lesion on a very small stem may girdle it and dwarf or kill a young plant.

At the time this work was in progress, 2 other isolates of *Glomerella cingulata* were being studied, one from *Chamaecrista* (6) and one from lupine (5). On July 13, 1943, these 2 isolates, together with the fungus from lespedeza and a culture of *Glomerella cingulata* from apple, were used to inoculate Kobe lespedeza plants about 1½ inches tall and growing in 6-inch pots. The plants were atomized with a heavy suspension of spores from culture, held in a moist chamber at 28° to 33° C. for 24 hours, and then placed outdoors under a cloth shelter. The first evidence of infection was seen after 48 hours on plants inoculated with the fungus from lespedeza. Many more spots were evident the following day, and after 4 days the leaflets were thickly spotted. There was no infection on any of the plants inoculated with the other fungi or on the controls. By the sixth day some of the heavily infected leaflets were turning yellow (Fig. 1, B) and falling and many stem lesions were present. The fungus was reisolated from some of the leaflets and the pathogenicity of the reisolate proved. This experiment not only proves the pathogenicity of the fungus from lespedeza but shows that the pathogen differs parasitically from the isolates from *Chamaecrista*, lupine, and apple.

In another experiment seedlings of several lots of lespedeza were inoculated to test their comparative resistance to this organism. The plants used were growing in 6-inch pots in the greenhouse and were about 8 inches tall.

On October 7, 1943, 11 different lots of lespedeza were atomized with a heavy spore suspension in sterilized tap water, held in a moist chamber for 48 hours, and then transferred to a cloth shelter outdoors. Plants in some of the lots were atomized with sterile tap water and held as controls. Infection was obtained on the following lots of *Lespedeza striata:* (Common) F.C. 22730[2] and F.C. 31057, (Tennessee 76) F.C. 22664, and (Kobe) F.C. 22731 and F.C. 30935. No infection was obtained on any of the strains of *L. stipulacea* (Korean); namely, F.C. 19601, F.C. 31480, F.C. 65280, F.C. 30888, and F.C. 19604; and none was obtained on the controls. This experiment suggests that the strains of *L. striata* are susceptible and that those of *L. stipulacea* are highly resistant. Field observations have not confirmed this entirely as is shown by the following tentative classification based on ratings made on experimental plantings in the field:

Highly resistant—(Korean) F.C. 31249 and selections 3 and 5 of F.C. 31249.

Resistant—(Korean) F.C. 19601, F.C. 19604, F.C. 30888, F.C. 31481, and F.C. 31485.

Susceptible—(Korean) F.C. 31480 and F.C. 31757.

Very susceptible—(Kobe) F.C. 22731, F.C. 30935, F.C. 22896; (Commercial Kobe); (Common) F.C. 31057 and F.C. 22730; and (Tennessee 76) F.C. 22664.

Just why some of these strains that proved to be susceptible under field conditions did not become infected under experimental conditions is not known. The field data indicate that, although they vary in their resistance, the strains of Korean are more resistant than those of Common and Kobe all of which were rated very susceptible.

Life History

An attempt was made to secure some data on how the fungus can be carried and how new infections are initiated in the spring. Four hundred seeds were divided into 8 lots of 50 seeds each. Four of the lots were planted in pots in steamed soil and without treatment, as controls; 2 lots were dipped into a heavy spore suspension and then planted in steamed soil; and the 2 remaining lots were planted in some of the same soil over the surface of which a heavy spore suspension was poured. The pots were all held in the greenhouse. The seeds were sown Feb. 3, 1944, and the seedlings were removed and examined March 7, 1944. Characteristic lesions were on the underground parts of the stems of some of the plants in the pots inoculated by pouring the spore suspension over the soil, and the fungus was recovered from some of these. A few similar lesions were on the plants grown from the inoculated seed. A very few were on the control plants. In neither of the latter groups, however, was the fungus recovered from any of the lesions; hence, final proof of their exact nature is lacking. There was no doubt that the disease was reproduced by soil inoculation.

[2] The seed of all F.C. lots were supplied by Mr. Roland McKee, Division of Forage Crops and Diseases, Plant Industry Station, Beltsville, Maryland.

Confirmation of the fact that the fungus can live in the soil and attack the underground parts of seedlings in the field is easily found. On May 6, 1943, dead and dying volunteer lespedeza seedlings 1 to 1½ inches tall were found with typical anthracnose lesions on many of the leaflets and on the stems as well. Some of the stem lesions were sufficiently large and deep to cause girdling; and plants thus girdled were dead, dying, or more or less stunted. Stems with smaller lesions appeared to be suffering little or no injury. Plants were taken to the laboratory, and isolations confirmed the nature of the disease.

On May 11, 1944, a heavy infection by the anthracnose fungus was found in lespedeza plants growing in some of the experimental plots. Typical leaf and stem lesions were present on many of the plants. Some were stunted and a few were dying as a result of the stem lesions. A section of sod about 6 inches square was taken up. The plants were then removed from the soil, washed, and examined. The seedlings were sorted into 3 groups, namely, healthy, slightly diseased, and severely diseased. The plants in the last group were more or less stunted and the stems had fairly deep lesions, especially below ground. The slightly diseased group had shallow lesions and were slightly if at all stunted. This random sample had 28 healthy, 85 slightly diseased, and 130 severely diseased plants, making a total of 88.5 per cent diseased. The healthy plants averaged about 4 inches tall, whereas the severely diseased ones ranged from 2½ to 3 inches. In order to get an idea of what might be the ultimate fate of such plants, 25 healthy, 50 slightly diseased, and 100 severely diseased plants were transferred to pots and held under conditions suitable for good growth. Final observations on June 3, 1944, showed that growth of the healthy plants had been excellent. Some of the slightly diseased ones were somewhat less vigorous, but others were as large as those in the healthy lot. A few of the plants in the severely diseased group died, but many remained stunted, some being ⅓ as tall as the healthy ones. It is evident that, under suitable conditions for the rapid development of the fungus, a high percentage of stem and leaf infection can be expected from the fungus that has lived over winter in the soil or on dead stems. No perfect stage was found on the old stems, and it seems reasonable to assume that the initial infection on the young seedlings in the spring results from mycelium growing in the soil or on the old plant material or from conidia produced on this mycelium. Of course, since the perfect stage developed in culture, its presence in the field cannot be discounted altogether, even though it was not found. Secondary infection probably is caused by conidia from the primary lesions. During dry periods there is little or no fruiting on the lesions, and the disease becomes very inconspicuous or may disappear entirely. It is most abundant during wet periods; and the damage done varies with the amount of inoculum present, the length of the wet period, and the stage of growth during that time. Only very young seedlings have suffered severely from the stem lesions or have been entirely girdled by them.

Effect of Temperature on Mycelial Growth

The effect of temperature on the growth of the fungus was studied in culture on 15 ml. of 2 per cent potato agar plus 1 per cent dextrose in Petri dishes. A loop of a heavy suspension of spores in sterile tap water was placed in the center of each dish, and 5 dishes were held at each temperature. The longest and shortest diameters of the mycelial colonies were measured and averaged at the end of 5 days and again after 10 days. At the lowest temperature (3.5° C.), the spores germinated, but no measurable mycelial colony was formed in 10 days. A small colony was formed at 12.5° C., the fungus grew rapidly at 22° and at 29° C., slowly at 31.5° C., and very slowly at 34.5° C. The spores did not germinate at 38° C. Later observations showed that some growth took place at 12.5° C. and that a small mycelial colony had been formed at 3.5° C. in 20 days. The minimum temperature for growth, therefore, was not reached. The maximum lies somewhere between 34.5° and 38° C. The optimum was somewhere between 22° and 29° C. This experiment was repeated in an effort to determine the optimum more precisely by changing some of the temperatures in that range. Average temperatures of 25.8° and 28° C. were secured. The results of this experiment, as well as the first, showed that the optimum appeared to shift, being higher at the end of 5 days than after 10 days. This is thought to have been due, at least in part, to the drying out of the medium at the higher temperatures. It was decided that the amount of growth during the first 5 days was probably a truer measure of the optimum, because appreciable drying of the medium had not yet taken place. In the second experiment growth was better at 28° than at 25.5° C.; and the optimum lay somewhere between these 2 temperatures, probably a little nearer the former figure, or possibly near 27° C. Shear and Wood (3) in discussing the temperature relations of *Glomerella cingulata* state that "the minimum, optimum, and maximum for the American material was found to be . . . 10°, 27°, and 32° C., respectively." It is probable that the optimum reported by these workers is very near that found by the writer for the fungus from lespedeza. The latter fungus, however, grew at 3.5° and at 34.5° C.; hence, these points differ somewhat from those given by Shear and Wood. Von Schrenk and Spaulding (4) state that the fungus causing the bitter rot of apple develops best at temperatures ranging from 33° to 38° C. This suggests that the upper limit for the growth of this fungus may vary considerably. These writers state also that the minimum for growth of their fungus is 2° C. which is very near the minimum for the lespedeza fungus.

Taxonomy

The original isolate from lespedeza at first formed only ascospores that resembled those of *Glomerella cingulata* (Ston.) Spauld. and Schrenk. These spores were slightly curved and measured 4.2–6.0 × 13.6–23 μ (av. 4.9 × 19.5 μ), which is well within the range given by Shear and Wood (3). Conidium-

forming strains were later obtained, and the original isolate was induced to form conidia on decaying apple. These conidia measured 3–6 × 13–22 μ (av. 4.1 × 18.2 μ), which also is within the range given by Shear and Wood. Setae were present among the spores but varied from few to abundant. They were dark brown to nearly black at the base, often becoming nearly colorless at the apex. The base of the seta is bulbous and is 6–10 μ wide at the broadest part. The seta tapers to a somewhat blunt point, is 70 to 180 μ long, and is usually 2- to 4-septate. The fungus differs in this last respect from *Colletotrichum destructivum* O'Gara which is described (1) as having setae which are often nodulose and continuous or obscurely 1-septate. Since no morphological difference was found that would enable one to distinguish the fungus on lespedeza from *Glomerella cingulata*, it is considered to be a strain of this species. The fact that no infection of lespedeza was obtained with the isolate of *G. cingulata* from apple, while abundant infection was obtained with an isolate from lespedeza under identical conditions, indicates that the latter may be a different parasitic strain.

CONTROL

The damage caused by the anthracnose fungus to lespedeza in the field is rather limited. What information is available indicates that serious damage to lespedeza is caused only under rather wet conditions, especially in the spring when the seedlings are small. Should the disease become sufficiently important to justify control measures, it seems probable from the results of inoculation tests and field observations that highly resistant varieties can be found, especially among the Korean strains such as F.C. 31249.

SUMMARY

An anthracnose of annual lespedeza caused by a strain of *Glomerella cingulata* is described. The disease causes more or less circular, elliptical, or angular brownish lesions from 1 to 5 mm. in diameter on the leaflets. The number of lesions per leaflet may vary greatly, but a single leaf spot is sufficient to cause a leaflet to drop off. The lesions on the petioles and stems are dark brown to nearly black and vary from circular to linear. They are of importance largely on young seedlings, whose stems may be completely girdled and the plants killed. The disease may be very prevalent in local areas during wet periods, especially during the late spring and early summer months, and may disappear during subsequent dry spells. The strains of *Lespedeza striata* appear to be more susceptible than those of *L. stipulacea*, although some of the latter are moderately susceptible. It is thought that, should control measures become necessary, resistant varieties may be found among some of the strains of the latter species such as F.C. 31249.

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RESPONSE OF SPRING BARLEY VARIETIES TO FLORAL LOOSE SMUT INOCULATION[1, 2]

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Loose smut of barley caused by *Ustilago nuda* (Jens.) K. and S. occurs generally wherever barley is grown, but is more prevalent in the humid and semi-humid areas of production. Losses are usually small in terms of percentage reduction of crop yield, but may be heavy at times. Several barley varieties widely grown in the North Central area of the United States are susceptible to *U. nuda*. With the exception of Trebi, no resistant variety is widely grown in this area. The organism causing loose smut can be controlled by hot-water treatment of the seed, but this method is both difficult and hazardous in application. It would be impractical for growers to treat with hot water all barley used for seed. An easier way to control the loose-smut pathogen would be the use of adapted resistant varieties, if such were available.

For several years the loose-smut disease has been given consideration in the barley-breeding program at the Wisconsin Agricultural Experiment Station. Attention has been given toward finding varieties with good agronomic type as well as resistance to loose smut and other important diseases. It would be desirable for new varieties to carry a practical type of resistance so as to prevent natural loose-smut epidemics.

LITERATURE REVIEW

Various techniques have been used for artificial inoculation with loose smut since Maddox (7) first showed that he could produce loose smut of barley by putting the spores on the ovary of the plant at flowering time.

Brefeld and Falck (1) used three methods to inoculate with the loose smut of wheat and barley. An atomizer was used to blow smut spores around the heads which were enclosed in a glass cylinder, producing from 9.5 to 20 per cent smut. Other methods included the introduction of either dry spores or a spore suspension into flowers by use of a small brush. Infection varied from 13 to more than 99 per cent smutted plants.

Freeman and Johnson (4) clipped the lemma and palea near the base of the awn, leaving an opening for introducing spores. In some cases dry spores were placed directly on the stigma with a brush or forceps, and this was their most effective method. Some heads were covered and others were moistened after inoculation. Optimum infection period was from full bloom until the ovary began to enlarge.

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[2] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.

[3] The writers acknowledge valuable assistance by D. C. Arny in the field work and assembling the data; and by V. I. Hack in the field inoculations. J. G. Dickson gave counsel in planning the project, and J. H. Torrie aided in statistical interpretation.

Broili (2) opened the flowers with a forceps or cut off the upper one-third of the lemma and palea and then blew in spores with an atomizer. He also employed Freeman and Johnson's method of opening the flowers with a forceps and dusting on spores with a brush (3). Seiffert (16) used Brefeld and Falck's brush method and a hollow needle resembling a spoon. The needle was dipped into spores, forced between the lemma and palea and the spores blown into the flower. He listed the varietal reaction from 0 to 94.4 per cent smut.

In his work with wheat loose smut, Piekenbrock (12) described an apparatus where dry spores were blown into the flowers by a blast of air produced by moving a piston in a cylinder. Modifying one of Freeman and Johnson's methods, Tapke (19, 20) inoculated barley flowers with loose smut by gently placing, with forceps, a small quantity of spores on the stigmas of flowers in the process of blooming. With high humidity after inoculation, Multan barley (19) developed 87 per cent smutted plants, and none under desert conditions. Zehner and Humphrey (24) obtained 33 per cent infection in Tennessee winter barley by injecting tillers in the apical growth region with a 14-hour spore suspension of *Ustilago nuda*. Zeiner (25) used Piekenbrock's method for testing parental and progeny responses for several barley crosses. Infection was from 0 to 78 per cent, and he also substantiated Piekenbrock's observations with wheat that the most favorable time for inoculation was shortly after flowering until 5–7 days after pollination. Nahmmacher (10) used a modification of Piekenbrock's apparatus, a rubber bulb replacing the piston and cylinder. Varietal reaction, inheritance of resistance, and physiological specialization studies were made where he differentiated 2 races of *U. nuda* on a pathogenicity basis. Vanderwalle (22) used a micropipette to inject a suspension of mycelium into the embryo. Developing plants were smutted, but it is not clear whether the fungus was *U. nuda* or *U. medians* Bied. since he (23) later mentioned sporidium formation. Peck, according to Thren (21), clipped the awns and treated the entire head *in vacuo* with dry spores. Moore (9) introduced a spore suspension into flowers of heads placed in a small glass chamber where pressure could be reduced. Wheat was more successfully inoculated than barley. Thren (21) used Nahmmacher's method for inoculating barley flowers, reporting high infection and increased survival counts when live-spore concentration was reduced. Oort (11) used the partial vacuum method of Moore for inoculating wheat and barley heads, and found the optimum time for infecting barley was near time of pollination. Lange-de la Camp (5) inoculated wheat flowers with a suspension of mycelium of *U. tritici* (Pers.) Rost. and kept heads moist for a few days. This is probably the first report of mycelium inoculation being successful. Middleton and Chapman (8) inoculated winter barley, using the vacuum and forceps methods. Livingston (6) used Moore's method and then maintained inoculated plants 72 hours in a chamber with 85–95 per cent relative humidity and at 15–30° C. Inheritance of resistance was studied. Semeniuk and Ross (17) enclosed

dry spores in 4 layers of cheesecloth and dusted heads of Newal barley several times. Poehlman (13) described a method using a spore suspension which was injected into individual flowers by a hypodermic needle. Ross and Semeniuk (14, 15) have also used this method. These workers have tested varieties and their results generally agree with those about to be reported in this paper.

METHODS AND MATERIALS

Inoculations

The present work with *Ustilago nuda* was reemphasized in 1936. Several methods were used in order to learn the one which would be most effective and most easily applicable. When inoculating barley heads it must be remembered that the individual flowers of a head are not all in the same stage of development. Several of the previously cited German workers removed small and lateral flowers. In the present work all flowers were left on the head with the exception of the very smallest ones at the base of the spike. One method used was the partial vacuum described by Moore (9). This was modified by using a larger glass tube than previously described in order that 2 or 3 and sometimes 4 heads could be inoculated at the same time. In addition, a solution of malt extract was used in order to increase germination and growth of the fungus after inoculation. A small amount of fish-oil soap was included in the spore suspension so as to decrease surface tension, permitting thorough wetting of the ovary and stigma.

A second method used was that first reported by Freeman and Johnson and later modified by Tapke where forceps carrying smut spores on finely-ground points were used to pierce the lemma and gently touch the stigma. A third method was that of clipping the upper part of the lemma and palea and dusting the inside of the flower with smut spores by means of a camel-hair brush. This type of inoculation had been previously used at Wisconsin in studying stripe of barley caused by *Helminthosporium gramineum* Rabh.

These three methods of inoculation were used in 1936 and 1937[4] and a portion of the heads were covered with glassine bags. The summary of the results is given in table 1. The bagging seemed to reduce smut infection during the 2-year period, when more than 900 inoculations[5] were made each year. Bagging was therefore discontinued for the inoculations beginning in 1938.

A fourth method of inoculation was introduced in 1938 when flowers were inoculated by use of a hypodermic needle, to which was attached a small rubber bulb containing dry spores of *Ustilago nuda*. After the needle pierced the lemma the bulb was squeezed in order to puff spores into the ovary. This is hereafter referred to as the "needle" method. In 1940, reference was made to this method in the annual report of the Wisconsin Agricultural Experiment Station.[6]

[4] The results were read the following year.

[5] In this paper the inoculation of all flowers of 2 barley spikes generally was considered a single inoculation.

[6] Annual report of the director of Wisconsin Agricultural Experiment Station. Bull. 449, p. 74.

TABLE 1.—*Influence of methods of inoculation on development of Ustilago nuda when many varieties of barley were used*

Year grown[a]	No. of inoculations[b]	Method of inoculation and percentage of smutted plants								
		Vacuum			Forceps			Clipped[e]		
		Bagged	Not bagged	Ave.	Bagged	Not bagged	Ave.	Bagged	Not bagged	Ave.
1937	150[c]	.....	16.04	.....	.....	6.76	.....	.....	11.89	.....
1937	907[d]	6.5	9.1	8.8	0.4	4.3	4.0	2.3	8.6	7.7
1938	954[d]	15.0	29.1	25.2	15.1	19.9	17.9	6.6	9.2	8.5

[a] Inoculations made the previous year.
[b] Two heads generally used for an inoculation.
[c] The same 50 varieties inoculated by each method.
[d] Large number of varieties not strictly comparable for each method.
[e] Upper part of lemma and palea clipped before dusting with spores.

A comparison of the needle and partial-vacuum methods with a large number of varieties is given in table 2. The results reported in tables 1 and 2 are not strictly comparable; but since the number of inoculations is large the results are thought to be fairly reliable. The needle method (Table 2) produced considerably more smut in the 1938 inoculations, the results of which were read in 1939. In 1940 the two methods gave very nearly the same percentage infection. Inasmuch as the needle method is much more easily used than the vacuum method, the latter was discontinued after the 1939 inoculations.

Since the data obtained from many varieties were composited in tables 1 and 2 it was thought desirable to compare the four methods of inoculation on Wisconsin Barbless and Oderbrucker varieties. These results, summarized in table 3, indicate that the needle and vacuum methods were more effective than the others. Only two years, 1938 and 1939, are available for comparison of the needle and vacuum methods. The vacuum method produced lower smut percentages than the needle method and was more difficult to use. Including Odessa, the needle method gave more infection for 5 of the

TABLE 2.—*Comparison of vacuum and needle methods of inoculation for Ustilago nuda, with many varieties of barley*

Year grown[a]	Method, number of inoculations[b], and smutted plants			
	Vacuum		Needle	
	Inoculations	Smutted plants	Inoculations	Smutted plants
	No.	*Per cent*	*No.*	*Per cent*
1939	635	24.4	181	42.3
1940	550	21.9	299	22.8

[a] Inoculations made the previous year.
[b] Two heads generally used for each inoculation.

6 varietal-year comparisons, with the exception of the 1940 results with Oderbrucker. While the summarized results should not be compared strictly, a total is given for the number of plants observed for all of the years and the percentage smut.

TABLE 3.—*Comparisons of inoculation methods when three barley varieties were inoculated with Ustilago nuda from day of pollination to 3 days after pollination*

Year grown[a]	Needle		Vacuum		Forceps		Clipped	
	Plants		Plants		Plants		Plants	
	Total	Smutted	Total	Smutted	Total	Smutted	Total	Smutted
	No.	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*
Wisconsin Barbless (C.I. 5105)								
1937	.....	.....	1919	7.2	1247	1.0	1805	4.9
1938	.....	.....	1601	16.4	359	1.4	852	2.3
1939	501	33.1	1163	26.0	.....	.....	.....	.....
1940	203	22.2	684	18.0	.....	.....	.....	.....
1941	1084	44.1	.....	.....	.....	.....	.....	.....
1942	267	15.0	.....	.....	.....	.....	.....	.....
1943	751	41.1	.....	.....	.....	.....	.....	.....
1944	86	58.8	.....	.....	.....	.....	.....	.....
Total or Av.[b]	2892	37.6	5367	15.4	1606	1.1	2657	4.1
Oderbrucker (C.I. 4666)								
1937	.....	.....	314	16.9	130	16.2	120	3.3
1938	.....	.....	115	36.5	357	4.5	157	12.1
1939	514	49.2	1019	32.2	.....	.....	.....	.....
1940	480	14.0	708	34.3	.....	.....	.....	.....
1941	1443	52.3	.....	.....	.....	.....	.....	.....
1942	535	37.0	.....	.....	.....	.....	.....	.....
1943	614	56.7	.....	.....	.....	.....	.....	.....
1944	429	69.9	.....	.....	.....	.....	.....	.....
Total or Av.[b]	4015	47.8	2156	30.9	487	7.6	277	8.3
Odessa (C.I. 934)								
1937	.....	.....	150	28.0	.....	.....	.....	.....
1938	.....	.....	321	36.1	.....	.....	.....	.....
1939	43	32.5	223	5.8	.....	.....	.....	.....
1940	53	58.5	163	43.6	.....	.....	.....	.....
1941	239	23.8	.....	.....	.....	.....	.....	.....
1942	10	90.0	.....	.....	.....	.....	.....	.....
1944	55	92.7	.....	.....	.....	.....	.....	.....
Total or Av.[b]	400	40.5	857	28.2	.....	.....	.....	.....

[a] Inoculations made the previous year.
[b] Total number of inoculations or average percentage of smut.

The stage of floral development at the time of inoculation is important. The different stages of development, using the two methods, needle and vacuum, are compared for susceptibility in table 4. The results for the needle method are given for a 6-year period from 1939–1944 and for the vacuum method for 3 years, namely 1938–1940. The results indicate that the barley flowers are most susceptible during and shortly after pollination.

Inoculations made later than 3 days after pollination gave a reduced infection. When Wisconsin Barbless was inoculated 4 days after pollination, smut was reduced to 6.5 per cent, and Oderbrucker infection was reduced to 5.1 per cent after 5 days following pollination. It is impractical to inoculate spikes before pollination because the heads have to be removed from the boot and the necks are rather weak and tender at this time. Therefore, it is desirable to wait until slightly after pollination. Nearly all of the inoculations were made near the time of pollination and since 1940 not later than 3 days after pollination.

Floral inoculation often affects the subsequent seed and plant development, frequently reducing germination and seedling vigor. If flowers are too young at time of inoculation, seed set is reduced more than when flowers

TABLE 4.—*Influence of stage of floral development on infection by Ustilago nuda, using two varieties of barley and two methods of inoculation*

Stage of floral development with reference to pollination	Wisconsin Barbless				Oderbrucker				Average infection, both varieties	
	Needle 1939–44		Vacuum 1938–40		Needle 1939–44		Vacuum 1938–40		Needle 1939–44	Vacuum 1938–40
	Plants	Smut	Plants	Smut	Plants	Smut	Plants	Smut	Smut	Smut
	No.	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*No.*	*Per cent*	*Per cent*	*Per cent*
Day before	111	45.9	.....	.....	179	60.9	.....	.....	51.1	.....
Day of	1334	41.4	217	36.9	1692	51.7	87	50.6	46.6	43.8
1 day after	1093	30.8	702	17.8	1687	47.3	555	35.5	39.1	26.7
2 days after	246	38.2	1405	21.7	321	31.8	656	27.6	35.0	24.7
3 days after	57	57.9	1124	15.8	126	25.4	514	35.6	41.7	25.7
4 days after	.....	.....	306	6.5	.....	.....	70	25.7	.....	16.1
5 days after	.....	.....	169	8.9	.....	.....	58	5.1	.....	7.0
6 days after	.....	.....	39	7.7	.....	.....	.....	.....	.....	.....

have been pollinated for a day or more. Such seeds are frequently light and chaffy, and secondary fungi may reduced stands. Treating inoculated seeds with organic mercury dust before planting reduces seedling losses and increases vigor. Hulls are often loose and fail to adhere to the caryopsis. Usually hulls are loosened most with lemma clipping and least with the vacuum technique. Plant stands vary from year to year when the same method is used, many factors probably contributing to the variation. Stands varied from 40 to 72 per cent and averaged 53 per cent with the needle method, from 1939 to 1944 inclusive. In 1939 and 1940 the vacuum inoculations produced 8 per cent greater stands. Thren (21), by reducing live-spore concentration to 1 per cent, raised the stand counts and yet maintained good infection.

The needle method was chosen by the authors because it produced the most infection and could be manipulated by one technician. Needle size found most successful was 20 gauge. Inoculum should be finely sieved and kept

dry, otherwise the needle may clog, which necessitates cleaning by a small wire. Reduced live-spore concentrations would likely increase stand counts and yet maintain high infection. The needle could also be used for injecting a spore suspension, though not done to a great extent in this work.

Inoculum

A composite inoculum was obtained from susceptible varieties grown currently in the nursery. Inoculum was collected from many varieties so as to maintain various races of the fungus which may be present in the nursery. Although specialized races are known in many species of Ustilago and also exist in *U. nuda*, no carefully purified race was used, thus avoiding a restriction in the application of the results. In rare cases smut used had been previously stored at low temperatures. Samples of the smut were germinated in order to determine purity of species, viability, and vigor. Floral inoculation with *U. nuda* only is reported in this paper.

Barley Varieties Tested

A large number of the varieties came from the C.I. collection.[7] The seed was originally supplied by R. G. Shands. Previous to the loose-smut test most of the varieties had been found resistant to the two sporidium-forming smuts. A large portion of these varieties has been inoculated with the stripe-causing fungus and the results reported by Shands and Arny (18). Many selections from the barley-breeding program in progress at the Wisconsin Agricultural Experiment Station have been tested for their reactions to *Ustilago nuda*. Like their parents, most of the hybrid selections were susceptible. The selections having numbers preceded by "H" were provided by R. G. Shands.

The varietal testing for reaction to *Ustilago nuda* has been in progress for about 10 years, and some of the resistant varieties have been hybridized with agronomically desirable varieties and their progenies have been tested for resistance. A few smooth-awned selections with resistance to *U. nuda* have been purified and are being tested for yield and adaptability.

RESULTS

Tests were from field inoculations and nearly all were field-grown. Only a small portion was grown in the greenhouse. Even though fairly extensive tests were made before 1939, the data in tables 5 and 6 give results mostly with inoculations since that time. The percentages of smut in Oderbrucker and Wisconsin Barbless for the period of 1939–1944 are 48 and 38, respectively, while some other varieties had 90 per cent or more, and still others had less than 5 per cent, thus indicating a satisfactory method for differentiating varietal reactions. The partial-vacuum technic was used for testing many hybrid selections and varieties, but the results were omitted except where the variety was not later tested with the needle method. Varieties or

[7] A world collection of barley varieties maintained by the Division of Cereal Crops and Diseases, U. S. Department of Agriculture.

TABLE 5.—*Loose-smut reactions of barley varieties artificially inoculated with Ustilago nuda*

C.I. No. and description[a]		Tests	Plants		C.I. No. and description[a]		Tests	Plants	
			Total	Infected Wt. Ave.				Total	Infected Wt. Ave.
		No.	*No.*	*Per cent*			*No.*	*No.*	*Per cent*
531	2	64	1488	44	1312[c]	N	8	207	7
595	H, N	5	51	25	1314	N	6	84	54
668	D, P	7	153	0	1315		7	107	73
918		5	291	47	1316	N	7	96	43
920		18	421	20	1330		12	316	28
923	B, S	9	212	48	1355[b]	S	4	136	44
934		14	400	41	1370	P, N	16	376	4
935		3	46	70	1379		5	95	75
936		16	596	4	1387		3	100	85
940		12	410	28	1408		5	190	3
967	2, B, N	10	173	0	1413	B	9	281	17
971		6	93	1	1417		2	82	51
972		5	180	51	1432		3	33	36
995		10	170	35	1433		2	36	81
998	N	7	186	19	1437		1	19	84
1016[d]		8	139	7	1438		5	97	5
1017		7	173	31	1441		3	66	21
1021		7	126	55	1443	I	4	24	0
1023		7	143	78	1445	2	3	79	53
1024		3	121	70	1455		3	21	52
1027	P, N	8	202	5	1466	2	4	49	14
1032	B, N	2	42	0	1467	B	3	52	37
1037		11	229	16	1468		6	168	28
1053		8	184	25	1470		11	381	15
1076		7	211	66	1557		4	104	3
1080		2	62	47	1585		4	45	2
1082		1	45	7	1603	A	5	105	15
1086	N	4	51	43	1604		6	179	18
1087		7	136	29	1610	A	8	133	5
1088[d]		1	43	9	1612	A, P	6	111	1
1090		5	72	21	1613		3	106	36
1110	2	4	102	77	1614		9	303	27
1111		10	418	39	1615		7	201	35
1119		7	231	4	1621		2	60	50
1131		3	108	57	1688		1	35	37
1142	2	4	91	60	1692		8	360	43
1179		2	20	70	1698[c]		4	145	46
1213		2	33	21	1756	2, N	2	57	39
1223		3	49	0	1774	H	5	118	3
1243	A	8	230	16	1918[c]		2	88	43
1248	P, N	16	238	13	1969	B	9	281	14
1257		6	162	57	2040		8	94	1
1263		10	300	39	2080	2	10	134	17
1284	S	6	186	4	2082	2	3	40	50
1296	D, P	10	193	1	2107		2	50	42

[a] All are white or blue, 6-rowed, rough-awned, and have adhering lemma and palea, except where other characteristics are indicated according to the following key:

2 = 2-rowed
I = intermedium
D = deficiens
N = naked kernels
A = Abyssinian intermediate
S = smooth awned
SS = semi-smooth awned
B = black
P = purple
H = hooded

B and P refer to black or purple color in lemma and palea of threshed grain of hulled barleys and to the color of the caryopsis in naked barley.

[b] Selection.

[c] Tested by partial-vacuum method.

[d] Tests by R. G. Shands gave greater infection.

TABLE 5.—(*Continued*)

C.I. No. and description[a]		Tests	Plants	
			Total	Infected Wt. Ave.
		No.	*No.*	*Per cent*
2135[c]	2	4	188	42
2203	H	3	86	7
2207	H, N	3	75	33
2208	B, H, N	4	79	0
2209	A	3	83	2
2213	I, N	9	238	32
2215	I, H, N	2	82	42
2219	2, H	3	31	13
2221	2, N	2	39	54
2223	2, H, N	4	60	5
2226	D, B	6	101	0
2237	A, H	2	51	42
2242[d]	P, H, N	3	55	6
2247	A, N	2	35	31
2253	N	6	120	23
2254	I	2	51	39
2257[d]	N	5	92	1
2261	N	5	55	7
2263	P	4	94	4
2267	A	2	41	37
2276	B	11	347	9
2277	P, N	4	70	4
2278	A	1	56	39
2280	I	2	24	29
2282		2	65	51
2284	A, B	7	135	4
2286	I, N	7	177	34
2318	N	6	89	2
2321	H, N	2	31	42
2330		1	68	59
2338	B	4	68	12
2344		2	23	39
2348		3	43	35
2351	N	4	66	3
2352	I, N	6	127	32
2353	B	4	146	19
2364		5	160	60
2381	A	5	130	23
2383	B	4	86	7
2432		5	127	32
2433		12	255	17
2437	2	2	23	83
2448	N	16	470	3
2467		11	280	36
2476		4	114	40
2480		4	94	49
2481		5	77	49
2482	H	4	76	63
2492		5	374	50
2497	B	5	64	0
2525		2	63	13
2526		2	19	63
2542		2	32	19
2573	S	2	22	18
2577	S	2	42	41
2877	2	1	12	58
2947[c]		21	842	24
3208–4		11	329	1
3210–2		11	271	1
3393–2		2	22	27
3402		6	60	3
3403[c]		5	244	58
3404		4	86	22
3408		2	28	14
3410		2	35	66
3413	A	2	28	43
3443		4	68	44
3446		1	19	74
3508		4	60	17
3530		1	47	85
3552		5	87	95
3553		3	59	86
3554		4	110	81
3556		1	10	70
3557		3	33	88
3558		4	103	89
3559		4	35	17
3560		2	23	83
3582		4	80	63
3634		3	40	88
3650		4	105	71
3724		2	48	54
3728		4	99	59
3745		4	35	31
3746		2	44	66
3776		3	29	66
3778		4	42	74
3808		2	53	100
3810		3	75	76
3816		4	39	77
3895–1		2	38	97
3896–1		1	10	90
3898		1	8	88
3902		2	55	89
3903		3	36	89
3905–1	B	3	55	38
3906–2	B	3	37	27
3906–3	P	2	25	28
3912–3	B	1	18	89
3914–1	P	1	22	23
3921–1		2	47	66
3921–2		1	7	57
3924–2		2	40	43
3969–1		1	41	34
3971		2	57	74
4032		2	74	80
4033		2	51	100
4033–1		2	67	88
4038		3	54	96
4041–2		2	75	36

TABLE 5.—(*Continued*)

C.I. No. and description[a]		Tests	Plants		C.I. No. and description[a]		Tests	Plants	
			Total	Infected Wt. Ave.				Total	Infected Wt. Ave.
		No.	*No.*	*Per cent*			*No.*	*No.*	*Per cent*
4049		1	17	82	5612		2	33	37
4118		8	170	74	5641		2	19	42
4184		2	37	65	5643		2	62	92
4201–1		2	43	49	5696[c]	B	3	51	31
4211	2	1	20	65	5841	A	1	21	19
4211–1		1	10	50	5899	P, N	10	167	6
4223		1	16	88	5998	S	1	20	35
4252	S	9	301	26	6001[c]		6	235	26
4289		11	487	34	6036	S	2	70	34
4376	D, B	2	56	84	6051	H	4	140	74
4425–1		4	110	30	6087	2, SS	3	44	71
4426		1	23	48	6088	S	12	369	68
4502–2		7	170	14	6093	S	5	213	43
4559		9	221	8	6109	S	4	112	25
4559–1		3	67	2	6199		1	18	100
4560–1[c]		4	122	10	6239	S	9	293	41
4561		3	82	12	6251		10	241	40
4573–1		2	27	7	6299	S	1	17	82
4576–1[c]		6	207	15	6311		1	15	80
4577[c]	S	18	691	20	6352		1	46	11
4577–1	S	5	164	23	6395	2	1	18	72
4585	2, S	6	132	51	6397	2	1	31	94
4585–1[c]		5	89	6	6421	2	1	25	28
4617[c]		6	183	29	6425	2	1	12	92
4622		11	197	16	6430	2	1	18	72
4623		17	341	13	6464	2	1	12	100
4624		2	39	8	6467		1	13	77
4633		3	33	70	6487		1	13	77
4637		7	137	42	6488	2	1	11	91
4666		132	4052	48	6503		6	286	48
4687	H	5	195	29	6531	2, B, S	8	132	60
4726[c]		6	265	24	6544		7	264	38
4731	2	2	45	18	6572	N	13	272	13
4757		1	39	46	6607		1	33	36
4801[c]	2	4	132	29	6608		1	56	39
4820		1	44	68	6609		1	42	36
4821	B	16	386	7	6611		1	54	37
4822	P, N	9	194	4	6614		3	66	2
4823	B	16	327	4	6615		1	49	38
4827[c]		5	175	38	6991	A	4	115	0
5027	2, S	3	55	49	7011	S	2	48	83
5030		10	389	48	7015	S	4	60	65
5105	S	106	2892	38	7030	S	5	155	71
5221		4	78	49	7055		2	48	2
5267		9	364	60	7069	S	7	298	36
5346		3	143	25	7115	S	4	112	67
5409	2	3	33	36	7116	S	4	119	24
5419[c]	D	3	86	36	7143	S	2	60	65
5459[c]	D	3	80	54	7165		3	149	24
5581		1	23	78	7166		13	570	20

selections having less than 20 plants for observation were omitted from tables 5 and 6 unless susceptibility was clearly denoted. When a variety was susceptible it was not tested further unless desirable from some breeding standpoint.

TABLE 6.—*Loose-smut reactions of barley hybrid selections and miscellaneous varieties when artificially inoculated with Ustilago nuda*

Hybrid selections[a] or varieties and description[b]		Tests	Plants	
			Total	Infected Wt. Ave.
		No.	*No.*	*Per cent*
X154–2–79		11	476	34
X173–5–4–1	S	7	227	59
X173–10–5–6–1	S	11	442	51
X182–8–1–2	S	13	447	61
X182–8–2–8	S	6	205	72
X182–8–3–3	S	5	162	62
X182–8–3–4	S	6	170	69
X182–8–3–7	S	6	163	59
X182–79–1–1	S	3	122	57
X182–243–1	S	3	78	33
X184–5	S	4	127	64
X184–11–15–1	S	4	108	45
X191–3–3	S	1	36	31
X191–16–2–1	S	9	286	68
X191–16–3–1	S	9	347	71
X191–24	S	6	242	57
X191–25	S	7	229	49
X207J–3–1	S	3	61	7
X207J–3–3	S	3	107	8
X212–1	S	4	152	30
X217–27	S	3	97	16
X217–57–1	S	3	61	2
X217–62	S	3	35	0
X226–2	S	2	31	66
X265–1	S	1	30	17
X301–1	S	3	79	44
H4–5–1–3–11–4	S	3	114	38
H4–8–7–3–1–1	S	5	203	67
H46–1–4–4–6		2	43	23
H47–91		2	48	6
H80–4–21		2	65	79
CC 12	S	7	93	0
CC 29		2	53	64
CC 146		6	176	19
WxWx		2	94	66
Wxwx		3	101	68
wxwx		6	203	58
Trebi Sel. (many leaves)		6	115	0
S.S. 1314		1	73	34
Lion Wis. 117–28	B, S	5	147	38
Michigan 110	2, S	7	123	33
Olli × Asplund		6	210	44
Tammisto 03639		2	35	31
Tammisto 04432		5	117	47
Tammisto 09234		4	141	58
Belgian	2	4	43	67
CP 170	2	6	173	45
CP 127422	2	10	265	2
Georgine Ped.	2	7	181	55

[a] Parentage of hybrid selections are as follows:

X39 —Oderbrucker (Wis. Ped. 5–1) × Lion (Wis. 117)
X154 —Oderbrucker (Wis. Ped. 5–1, C.I. 4666) × Korsbyg (Wis. 97–3)
X168 —X39–5–8–4–1 × Oderbrucker (Wis. Ped. 6, C.I. 1529)
X173 —X39–9–3–6–8 × Oderbrucker (Wis. Ped. 5–1)
X182 —Wis. Barbless (C.I. 5105) × Olli (C.I. 6251)
X184 —Wis. Barbless (C.I. 5105) × Peatland (C.I. 5267)
X191 —Wis. Barbless (C.I. 5105) × Newal (C.I. 6088)
X207J—Trebi (C.I. 936) × Wis. Barbless
X212 —Chevron (C.I. 1111) × X168–5–1
X217 —Trebi × Wis. Barbless
X226 —H4–8–15 × X182–21–2
X265 —Wis. Barbless × Pillsbury (C.I. 7166)
X301 —X182–8–2–8 × F_1 (Trebi × Pillsbury, C.I. 7166)
H4 —Wis. Barbless × Chevron
H46 —Chevron (C.I. 1111–5) × Brachytic (Minn. 78–4, C.I. 6572)
H47 —Chevron × Trebi (C.I. 936)
H80 —Chevron × Hillsa (C.I. 1604)

[b] See table 5 for description.

The results of varietal tests are given in table 5 for C.I. numbered varieties, and in table 6 for hybrid selections and miscellaneous varieties. The C.I. number, description, the number of tests, the total number of plants observed, and the average percentage of infected plants on a weighted basis are given. If 2 or more tests are recorded they probably were from different years. The weighted average was determined by use of the total plants

in all tests of an individual variety. Names and descriptions of a large part of the tested C.I. varieties were given by Shands and Arny (18). Nearly all of the selections from hybrids listed in table 6 are 6-rowed and smooth-awned. A small portion of the miscellaneous varieties listed in the latter part of table 6 are 2-rowed, and nearly all are rough-awned.

DISCUSSION

The two varieties of barley used most frequently as inoculated controls in these experiments are Oderbrucker and Wisconsin Barbless. Oderbrucker had 48 per cent infection and Wisconsin Barbless had 38 per cent. This represents 132 and 106 tests, respectively, of about 30 plants per test. Infection percentages varied within wide ranges, but it is thought that these averages are fairly representative for these varieties.

In order to obtain an estimate of the variability present and the percentage of smut necessary to separate varieties, the analysis of variance was applied to the results of 40 varieties that had been tested for 4 consecutive years. The varieties were placed into two groups, those with less than 20 per cent or more than 80 per cent infection and those which had more than 20 per cent and less than 80 per cent infection. For the first group the smut percentage necessary to separate varieties was lower than for the second group, decreasing as infection approached 0 or 100 per cent. Variability within a variety as measured by the standard deviation was 7.7 per cent for the first group and 14.9 for the second. On the basis of the 4 years, the amount of infection necessary to differentiate varieties in the first group was 11 per cent, and 21 per cent for the second. While these values cannot be applied directly to the results in tables 5 and 6, they can be used as a guide in interpreting the data and for the separation of the varieties. The values would be larger for comparisons including less than 4 years' data and smaller for comparisons including more than 4 years' data.

In testing 300 varieties from the C.I. collection a total of 4 had 100 per cent smut. These four varieties were C.I. numbers 3808, 4033, 6199, and 6424. Of more interest, however, from a plant-breeding standpoint are 36 varieties which had less than 5 per cent infection. In this group 9 varieties had no infection; they are as follows: C.I. 668, 967, 1032, 1223, 1443, 2208, 2226, 2497, and 6991. Evidently these were resistant, but infections might occur under conditions of more extensive inoculations or with different races. The 300 varieties were rather evenly distributed in different infection classes from 0–100 except for the 30–40 per cent groups and the classes containing less than 5 per cent.

It is of interest to note the place of origin of the varieties in relation to their smut reactions which are given in table 7. Abyssinia was the place of origin of the largest number of resistant varieties, while varieties from Egypt and North Africa were generally susceptible. No tested variety from Russia was highly resistant. Several of the varieties from Manchuria had moderate resistance. China and India had a few varieties fairly resistant and several fairly susceptible.

TABLE 7.—*Source and number of varieties in various infection classes when artificially inoculated with Ustilago nuda*

Source or country	Number of varieties in 5 infection classes				
	0–3	4–15	16–30	31–60	61–100
Abyssinia	8	7	6	5	3
Asia	....	3	1	3	1
Australia	1	2	1	1	3
China	3	1	1	9	....
Egypt	....	....	1	3	18
India	2	6	6	7	....
Japan	....	2	2	....	....
Manchuria	1	8	7	4	1
Middle East	....	2	2	3	1
North Africa	....	2	2	6	13
Northern Europe	....	3	1	14	9
Russia	....	....	4	11	8
Southern Europe	....	1	1	....	2
Total	15	37	25	66	59

Most of the hybrid selections given in table 6 were tested for yield as well as for several diseases. Some of these hybrids were made before the parental disease reactions were learned, and some were made primarily for quality factors. Therefore, many of the selections have no appreciable resistance to *Ustilago nuda*, while those with resistance have derived it from either Trebi (C.I. 936) or Dorsett (C.I. 4821).

In table 8 is given the loose-smut reaction of certain commercial barley varieties grown in the United States and Canada. Most of the commonly-grown varieties were relatively susceptible. Trebi and Tregal were resistant, and Warrior had no infected plants, although the latter would doubtless have some infection if studied more extensively. The Manchurian varieties varied in their responses to loose smut, O.A.C. 21 having 15 per cent and Minnesota 184 having 59 per cent infected plants. Peatland, Mars, Newal, Plush, and Missouri Early Beardless are considered as susceptible

TABLE 8.—*Loose-smut reactions of some commercial barley varieties grown in the United States and Canada*

Variety	C.I. No.	Smut	Variety	C.I. No.	Smut
		Per cent			*Per cent*
Bay[a]	7113	32	Olli	6251	40
Glabron	4577	23	Peatland	5267	60
Hannchen	531	44	Plush	7030	71
Kindred[a]	6969	78	Pliter	6036	34
Manchuria N.D. 2121	2947	24	Regal	5030	48
Manchuria Minn. 184	2330	59	Spartan	5027	49
Manchuria O.A.C. 21	1470	15	Trebi	936	4
Mars	7015	64	Tregal[a]	6359	0
Missouri Early Beardless	6051	74	Velvet	4252	26
Newal	6088	68	Velvon	6109	25
Oderbrucker	4666	48	Warrior	6991	0
Odessa	934	41	Wisconsin Barbless	5105	38

[a] Data by R. G. Shands

varieties. Other varieties had less infection but are considered moderately susceptible.

In breeding new varieties of barley, it is desirable for the new selections to be resistant to more than one of the major diseases. Shands and Arny (18) gave the stripe reactions for a fairly large number of barley varieties. The loose-smut reaction is given herein for 139 varieties recorded in that paper. There were 17 varieties that had less than 15 per cent stripe and loose smut, a reaction that was considered resistant to each of the diseases. The following are the varieties and their C.I. numbers:

C.I. 936 Trebi	C.I. 2318 Kharsila	C.I. 6352 Cebada 97A
1969 Chinese Black	2338 Nigrum	6572 Brachytic
2040 Canada Winter	3402 Gujarkhan	6991 Warrior
2261 Pusa	4821 Dorsett	7055 Titan
2276 Gatami	4823	
2284 Black Abyssinian	5899 Murasaki Mochi	C.P. 127422

Trebi and Cebada are similar in their disease and agronomic responses. Both are large-kerneled and have a tendency to be high in yield under dry-land conditions. Titan and Warrior very likely derived their resistance from the Trebi parent. Dorsett and C.I. 4823 are both black with brittle rachises and appear alike in many other respects. Brachytic and Murasaki Mochi are naked varieties and are not considered generally as good breeding stocks. Murasaki Mochi has a waxy endosperm. C.I. 2284 is classified as an Abyssinian intermediate type with black kernels. C.P. 127422 is a 2-rowed variety of German origin.

A large proportion of the selections being tested in the Wisconsin breeding program now have resistance to loose smut in one of the parents. Some of these selections are being tested for yields as well as disease reactions. Thus far the most promising source of resistance to loose smut has been Trebi. Unfortunately Trebi has a weak straw under Wisconsin conditions and most of its derivatives likewise have this undesirable agronomic characteristic. At present, efforts are being made to combine resistance to several major diseases with good agronomic type and smooth awns.

SUMMARY

Several methods of inoculating barley varieties with loose smut have been compared. The most effective and easily manipulated method consists of injecting dry spores into barley flowers by the use of a hypodermic needle to which is attached a small rubber bulb containing chlamydospores of *Ustilago nuda*. This is called the "needle" method and was used for testing varietal reaction. The reactions of 300 barley varieties from the C.I. collection are given. Wide varietal differences in percentage of infection were found. Several varieties possessed a high degree of resistance to the composite inoculum. Many selections from the breeding program have been tested for their response to *U. nuda*. Some of these are smooth-awned selections with loose-smut resistance and fairly good agronomic character-

isties. Efforts are being made to combine resistance to the several major barley diseases and good agronomic type with good malting quality.

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SEED TRANSMISSION OF BACTERIAL BLIGHT OF SUGAR BEET

P. A. Ark and L. D. Leach

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In the summer of 1943, the writers' attention was called to a disease in beet-seed fields in northern California and southern Oregon which involved a rapid dying of the leaf blades, commonly beginning at the tip of the blade and gradually becoming systemic. Later investigation of this trouble showed the disease was bacterial in nature. Although certain aspects of this disease have been described (1, 2, 3), the writers have observed some new features that are herewith discussed.

In 1909, Brown (1) described a bacterial disease of the leaves caused by *Phytomonas aptata*. The disease was observed by Townsend in Utah and California in 1908 (1). Brown and Jamieson (2), reporting on the causal bacterium of this disease of sugar beet from California, stated that "so far as the writers know, this organism has not been found in the field attacking the beet root, and, as none of the field beets with affected leaves had any root trouble, it is thought that the disease in the field is confined strictly to the leaf." Recently attention has been called by Carsner (3) to the occurrence of black leaf spot and stalk streak of sugar beet in the Pacific Northwest, caused by *Ph. aptata*.

The disease has been observed in moderate amounts in the Shasta Valley of northern California and in the Medford and Willamette Valleys of Oregon, at elevations above 4,000 feet where low temperatures occur frequently during the growing season. It is difficult to determine the amount of damage caused by bacterial blight because of complications induced by frost, insect injury, and other causes. The disease has not been observed in fields intended for sugar production although a few leaf infections were found on an overwintering test plot at Davis, California, planted with contaminated seed.

One of the striking symptoms of the disease in California and Oregon is the rapid dying of leaf blades. Under excessively moist conditions the dead parts become slimy and necrosis spreads quickly into the veins and the petioles of the leaf. Sometimes only isolated, black leaf spots are present. In other cases, necrosis begins in a wedge-shaped area near the margin of the leaf and spreads from there into the main veins and midrib, at times resulting in wilting of the leaf (Fig. 1, A and C). On the seed stalk, black streaks frequently extend from the tip to the base (Fig. 1, C). Petioles in the early phases of the disease have light to jet-black discoloration in the fibrovascular bundles, and the stalk, upon being split longitudinally, has dark cavities containing numerous bacteria (Fig. 1, D). The discoloration can usually be traced into the root where invasion was observed (Fig. 1, E). Invasion of the stalks causes brown to black discoloration of the spikelets and discoloration of the seedballs, which on culturing yield the pathogen.

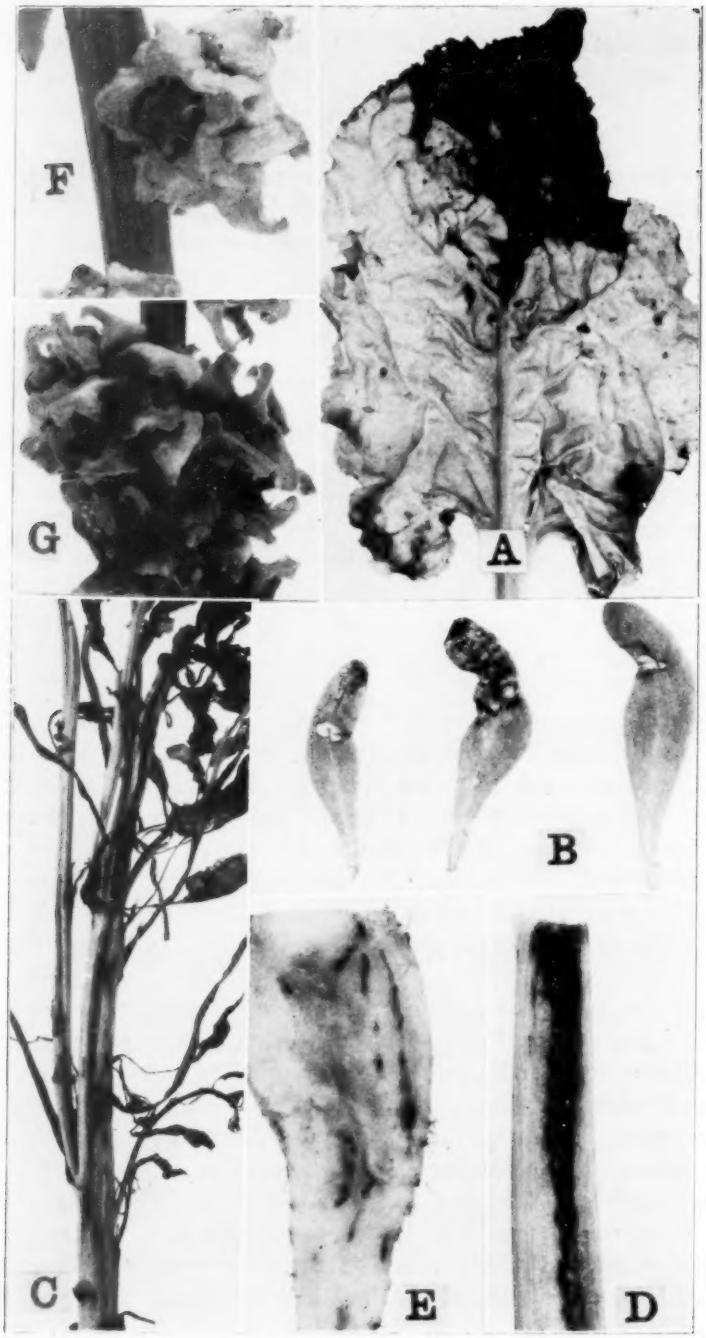

FIG. 1. Bacterial blight of sugar beet. A. Sectorial infection at tip of the leaf. B. Infections on the cotyledons of sugar-beet seedlings from contaminated seed. C. Seed-stalk infection. Note black streaks along the stem extending from top to bottom. D. Longitudinal section of the stalk shown in C. E. Internal discoloration of a root infected with *Phytomonas aptata*. Natural infection. Bacteria were abundant in the discolored tissues. F. Healthy seedball. G. Infected seedballs (blackened).

Microscopic examination of diseased tissues revealed an abundance of bacteria. Inoculation tests with isolants from different parts of a diseased plant into young sugar beets growing in the greenhouse were successful in all cases. Symptoms typical of the disease were produced on leaf blades and petioles when they were inoculated by puncturing with a needle or by smearing the inoculum on the surface and rubbing with carborundum powder (6).

The bacterium isolated from various parts of the affected sugar-beet plants corresponds in all particulars with *Phytomonas aptata*, as described by Brown and Jamieson (2).

The bacteria seem to prefer the vascular elements of infected plants where they were found in much greater numbers and far in advance of those in the surrounding parenchyma.

Since the disease is not confined to the leaves but occurs in any or all parts of the plant, and may even cause death, it seems appropriate to apply a more descriptive and inclusive designation, namely, bacterial blight of sugar beet rather than leaf spot, or black streak, which are only phases of systemic infection.

Carsner (3) suggested, on the basis of his field observations, that the causal organism may be seed borne. The writers found usually not over 5 to 10 per cent infected seedlings from any lot grown in pasteurized soil. If seed from the same lot was germinated in Petri dishes, about 50 per cent of the seedlings were infected. Diseased seedballs can be detected by direct microscopic examination of sections made from them, by culturing, and by germination in Petri dishes or in sand. Such seedballs are noticeably darkened (Fig. 1, F and G) but similar darkening may also be induced by insect injury or other causes.

The first symptom in seedlings grown from contaminated seed (Fig. 1, B) is indicated by a small depression on either side of the cotyledons which becomes water soaked, sometimes developing a light-yellow halo. Gradually the affected parts of the cotyledons become soft and black. One to several lesions may occur on a single cotyledon, resulting in distortion. Seedlings grown in high humidity develop lesions on the true leaves. Thus, the pathogen can spread from infected cotyledons to other parts of a plant under favorable conditions of temperature and humidity.

Seedling infection was controlled in the greenhouse by treating field-contaminated seed with New Improved Ceresan (ethyl mercury phosphate) dust at the rate of ½ oz. per 100 lb. of seed, New Improved Ceresan dip (1–1,200), and Arasan (50 per cent tetramethyl thiuram-disulphide) dust at the rate of 4 oz. per 100 lb. of seed (Table 1). From these tests it is apparent that the disease is seed borne. However, no attempt was made to determine if the bacteria are primarily surface contaminants or if they are internal.

Brown and Jamieson (2) reported that *Phytomonas aptata* is capable of infecting the following plants by artificial inoculation: sweet or bell pepper

TABLE 1.—*Seed treatments to control bacterial blight of sugar beet*

Treatment	Healthy plants	Diseased plants	
	Number	*Number*	*Per cent*
Check, no treatment	176	11	5.9
	194	12	2.4
New Improved Ceresan, Dust	226	0	0
	381	0	0
Dip	270	0	0
	243	0	0
Arasan, dust	259	0	0
	272	0	0

(*Capsicum annuum* L.), kidney bean (*Phaseolus vulgaris* L.), common eggplant (*Solanum melangena* L. var. *esculentum* Nees.), and lettuce (*Lactuca sativa* L.). Paine and Branfoot (5) in 1924 reported on a disease of lettuce which they first thought was caused by *Phytomonas marginalis* (Brown) Bergey *et al.*, but later they attributed it to *Ph. aptata*. It had affected 75 per cent of the lettuce plants in a private garden in England. The organism also caused a leaf spot on nasturtium (*Tropaeolum majus* L.) in nature according to Jamieson (4). The writers were able to produce the disease on all of these plants by needle inoculations with the isolants obtained from many diseased specimens of sugar beet. In addition, the broad bean (*Vicia faba* L.) was successfully inoculated with *Ph. aptata* which produced long black streaks on the stems of greenhouse-grown plants. When the inoculated plants were transferred to a moist chamber the damage was noticeably increased. Swiss chard (*Beta vulgaris* L. var. *cicla* L.) is also susceptible when the leaf blade or petiole is inoculated by needle.

SUMMARY

1. *Phytomonas aptata*, previously described as causing a leaf spot of sugar beet, is now known to produce blighting of the leaves, black streaking of seed stalks, and internal root necrosis.

2. Seed from blighted stalks are heavily contaminated with the bacterium and produce diseased plants upon germination. Seed transmission was prevented by using New Improved Ceresan dust or dip, or Arasan dust.

3. In addition to sugar beets, sweet pepper, nasturtium, lettuce, eggplant, and beans, previously reported to be susceptible to *Phytomonas aptata*, Swiss chard and broad bean have been infected.

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EFFECT OF MINERAL NUTRITION ON THE VIGOR AND SUSCEPTIBILITY TO BLIGHT OF OLD JAPANESE CHESTNUT TREES

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About 500 Japanese chestnut trees (*Castanea crenata* Sieb. and Zucc.) still survive from an original planting of 2,000 trees made 50 years ago near Fairfax Station, Virginia.[2] Most of these trees are in various stages of senility. It seemed desirable (*1*) to determine whether such trees could be benefited by the application of plant nutrients, and (*2*) to observe the effect of fertilization on incidence of infection and the susceptibility of the trees to the chestnut blight fungus, *Endothia parasitica* (Murr.) P. J. and A. W. Anderson.

In the spring of 1944 sixty-four of the surviving trees, of about equal vigor, were selected for treatment. They averaged 15.6 inches in diameter at breast height (d.b.h.), 33 feet in height, and 31 feet in crown spread. The experiment included seven fertilizer treatments and a check. Each treatment was replicated eight times in a randomized arrangement. Fertilizers were applied March 2, 1944, and a second application, of nitrogen only, to some of the trees was made on March 2, 1945. The potash and phosphate fertilizers were applied in "punch holes" 2 feet apart, and the nitrogen fertilizer was broadcast. Of the 64 trees, 26 were inoculated on 9 lower branches of each tree during the winter (December 19, 1944, to March 2, 1945) with 9 isolates of chestnut blight fungus from Orange, Massachusetts, and 9 from Bell, Maryland. One inoculation for each isolate of chestnut blight from each source and a check of sterile agar were placed on each branch. The cultures were isolated in October, 1944, from young cankers on American chestnut sprouts. Results of the inoculations were observed and d.b.h. and current shoot-growth measurements were made on July 20, 1945.

The various fertilizer treatments and the shoot lengths obtained are shown in table 1.

An examination of the data by means of the conventional analysis of variance indicates the following conclusions: (*1*) Fertilization with potash and phosphoric acid had no significant effect on shoot growth. (*2*) Nitrogen at the rate of 150 lb. was without significant effect. (*3*) Nitrogen at the rate of 300 lb. increased the shoot growth significantly in 1944, but the second application, in 1945, had no significant effect.

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[2] The authors wish to express their appreciation to Mr. Charles D. Hamel, McLean, Virginia, owner of the orchard, for his cooperation.

Under the conditions of this test no fertilization except a very heavy application of nitrogen had any significant effect. Shoot growth on the trees fertilized with potash and phosphoric acid was not significantly greater than on the nonfertilized trees. The data do not permit statistical evaluation of the effects of climatic differences in the two years.

There is no correlation between shoot length and trunk diameter in the trees in this experiment.

The results of the canker inoculations are more difficult to interpret than are those of the shoot length. One Massachusetts and one Maryland isolate of the fungus produced no cankers at all while other isolates of each group produced only two to three. Some of the trees were susceptible, as evidenced by the cankers that developed following inoculation, and others appeared

TABLE 1.—*Influence of fertilizer treatment on current shoot growth of 50-year-old Japanese chestnuts*

Treatment No.	Fertilization,[b] lb./acre	Ave. total shoot length per tree[a]		
		1944	1945	Both years
		cm.	*cm.*	*cm.*
1	None	175.6	201.3	376.9
2	300 lb. N annually	218.6	225.8	444.4
3	150 lb. N annually	192.8	225.4	418.1
4	300 lb. N once	223.1	226.0	449.1
5	300 lb. N once + P–K in 1944	199.8	234.0	433.8
6	150 lb. N annually + P–K in 1944	194.1	217.4	411.5
7	300 lb. N annually + P–K in 1944	205.4	226.8	432.1
8	P–K in 1944	162.5	187.8	350.2

[a] Average total length of 10 shoots per tree, one tree per replicate, 8 replicates.
[b] Nitrogen applied as ammonium nitrate. P–K (100 lb. P_2O_5 plus 75 lb. K_2O) applied as superphosphate and KCl, respectively.

to be entirely resistant. The data obtained are thus scattering, with a great many zero values. This renders statistical treatment difficult and of doubtful value. Nevertheless some of the differences in number and area of cankers per tree are so large that there can be little doubt of their true significance. Table 2 presents the average number of cankers and canker area per tree for each fertilizer treatment.

When P–K was applied without nitrogen, Treatment 8 (all of the P–K treatments were applied a year before inoculation), the incidence and susceptibility to canker, as measured by the number and area of cankers per tree, respectively, were both much greater than with all but one of the treatments that consisted of nitrogen only. This exception occurred where 300 lb. of nitrogen were applied annually (Treatment 2) in conjunction with the Maryland blight isolates. On the Massachusetts isolates this treatment did not appear to differ significantly from the other treatments with nitrogen only. But when nitrogen was applied in conjunction with P–K at the lower rate annually, or once at the 300-lb. rate (Treatments 5 and 6, respectively), it appears to have rendered the trees less susceptible. When applied again

at 300 lb. per acre near the time of inoculation it failed to give this result. This observation appears to correlate with the observation that susceptibility increased when 300 lb. of nitrogen without P–K were applied annually. With the exception just noted, nitrogen treatments without P–K, whether made once or annually, had no significant effect on canker incidence or area of cankers.

The average size of the cankers varied, but in a manner that appears to have been random; there seems to have been no connection between canker size and the fertilizer treatments in this experiment. There was also no apparent significant difference between the Massachusetts and Maryland isolates in the average size of canker produced (4.2 and 4.5 sq. cm., respec-

TABLE 2.—*Effect of fertilization on occurrence and development of blight cankers induced by inoculation of 50-year-old Japanese chestnut trees*

Treatment No.	Fertilization, lb./acre	No. of trees	Av. No. of cankers per tree	Av. canker area (sq. cm.) per tree
Endothia isolates from Massachusetts				
1	None	3	1.0	2.4
2	300 lb. N annually	3	1.6	6.8
3	150 lb. N annually	2	1.5	6.9
4	300 lb. N once	4	1.0	5.5
5	300 lb. N once + P–K in 1944	3	1.7	5.4
6	150 lb. N annually + P–K in 1944	4	2.5	5.7
7	300 lb. N annually + P–K in 1944	3	3.3	19.1
8	P–K in 1944	4	3.0	14.2
Endothia isolates from Maryland				
1	None	3	1.0	2.8
2	300 lb. N annually	3	2.0	12.7
3	150 lb. N annually	2	0.5	2.1
4	300 lb. N once	4	0.8	3.4
5	300 lb. N once + P–K in 1944	3	0.7	2.1
6	150 lb. N annually + P–K in 1944	4	2.2	4.9
7	300 lb. N annually + P–K in 1944	3	3.3	10.3
8	P–K in 1944	4	3.0	14.9

tively) or in the total number of cankers produced by each (52 and 46, respectively). There is thus no evidence, from this experiment, that the longer established group of Massachusetts isolates are any less virulent than the Maryland isolates that appeared more than 10 years later.

It is clear that, under the conditions of this experiment, P–K applied a year previous to inoculation increased canker incidence and susceptibility to the canker fungus, but this effect was modified in a complicated manner by treatment with nitrogen. These results are of sufficient importance to warrant further study. Field observations made elsewhere during six growing seasons suggest that potassium chloride is an unfavorable form of potash for chestnuts. The current observations may thus be connected with some toxic action of the chloride ion.

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RUST AND PHOSPHORUS DISTRIBUTION IN WHEAT LEAVES

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Despite the many years which have elapsed since the early work of Marshall Ward (13 and 14) on the physiology of obligate parasitism, this complex is still in many respects an enigma. One of the phenomena which has been fairly well established is that the rusts and the powdery mildews increase the respiration of their hosts. As early as 1915 Reed and Crabill (12) demonstrated that apple leaves infected with *Gymnosporangium juniperi-virginianae* respire more than noninfected leaves. Yarwood (15 and 16) showed that a similar change takes place when excised clover leaves are inoculated with either rust or mildew. Pratt (11) found that powdery mildew increases the respiration in wheat plants and also that the higher rate is not due to the respiration of the mildew mycelium. More recently Allen (1, 2, 3) has shown that in the powdery mildew of wheat the increase in the respiration and metabolism occurs during the period of rapid growth and maturation of the parasitic colony and that a decline sets in after this period. Associated with these phenomena is an accumulation followed by a decrease in the quantity of carbohydrates. This increased metabolism is mainly due to the oxidation of glucose. The importance of carbohydrate metabolism in the physiology of obligate parasitism is then evident.

Some of the vital factors in the degradation of glucose are the phosphate transfer enzymes, and James and Bunting (7) have shown that such enzymes are also operative in barley, a host of stem rust. The importance of such phosphorus enzymes suggests the possibility that an accumulation of phosphorus may be linked to the high rate of utilization of the sugars, so that an increase in phosphorus would allow greater enzyme transfer and a more rapid oxidation and respiration. Humphrey and Dufrenoy (6) have indicated that in oats infected with crown rust, phosphorus is released by infected cells and made available to the parasite, and they postulate a transfer of phosphorus into the infected regions. Little more is known of the phosphorus relations of infected leaves.

The current investigations had two objectives: (1) the development of a technique for the study of phosphorus relationships, and (2) a study of the distribution of phosphorus in normal leaves and rust infected leaves.

METHODS

The paucity of information on the physiology of obligate parasitism is due in large part to the fact that no means of culturing an obligately parasitic fungus *in vitro* has been known. An investigator could obtain and study only the spores of the parasite apart from the host plant. Any re-

[1] These studies were conducted while the senior author was on the staff of the University of Delaware.

search must therefore deal with activity of the pathogen at work within its host. Humphrey and Dufrenoy (6) resolved this difficulty by the use of staining techniques, but even this method had severe limitations. Quantitative data are difficult to obtain, and observations on the density of stain cannot be easily reproduced. To overcome such difficulties, a tagged element, radiophosphorus, was used in these investigations. The use of radioactive phosphorus enables the investigator to detect very small quantities of the element, for the assay is dependent upon the disintegration of the atom, and theoretically the presence of each atom can therefore be recorded. The method is relatively simple because no complex chemical separations are necessary. Finally, radiographs can pictorially locate any differences in concentration of the element in various parts of the host. As far as is known, the radioactive phosphorus, P^{32}, is metabolized by the living organism in a manner similar to the common form of phosphorus (5) and its biologic activity is generally accepted as representative of the normal isomer.

Only one host, Little Club wheat, and one pathogen, *Puccinia graminis tritici* race 34, were employed in these experiments.[2] The radioactive phosphorus, P^{32}, was obtained from the Massachusetts Institute of Technology[3] as phosphoric acid and converted to KH_2PO_4 for these experiments. Hoagland's complete nutrient solution (9) was the basic medium for growing the wheat seedlings, with but one change, the substitution of the radioactive phosphorus salt for the usual form. A Geiger counter (1) was used for the analysis of phosphorus, and ordinary Verichrome film served for the radiographs. The Geiger counter[4] was mounted 0.5 cm. above the material to be analyzed.

Wheat seeds were disinfected with mercuric chloride and allowed to germinate and grow in a moist chamber until the first true leaves just ruptured the coleoptiles. The seedlings were then transferred to the nutrient solution contained in small circular glass dishes, 6 inches in diameter and 3 inches high, which contained $\frac{1}{4}$-inch mesh wire for support of the plants. When the plants were about 100 mm. tall, one side of the distal half of each leaf was inoculated with the rust by brushing the leaves with a suspension of urediospores in water; the plants were then placed in a moist chamber for two days. An equal number of check plants was treated similarly except that they received no inoculum. The plants were kept in a constant temperature room at $20° \pm 2°$ C. under a 200-watt Mazda lamp during the entire experiment. Only the first true leaf was inoculated and all other leaves were clipped off as soon as they appeared. Under these conditions, flecks first were observed 4 days after inoculation, and sporulation of the

[2] The wheat was furnished by Dr. C. S. Holton of the United States Department of Agriculture and the rust by Dr. H. A. Rodenhiser of the United States Department of Agriculture.

[3] The radioactive phosphorus was obtained through the courtesy of Dr. R. D. Evans of the Massachusetts Institute of Technology.

[4] The counting equipment was obtained from Dr. A. J. Allen, University of Pittsburgh.

rust fungus occurred 10 days after inoculation. No additional nutrient solution was added to the dishes until the fifth day after inoculation. From then on, sufficient solution was added every two days to bring it to the original volume. Radioactive phosphorus was present only in the original medium, and the normal inactive salt in all the later solutions.

Four plants were used for each analysis with the Geiger counter and three replicate analyses were made 2, 5, and 12 days after inoculation. The leaves were used either whole or cut into two sections, the infected distal end and the noninfected basal portion. Each leaf section was further divided into ¼-inch sections to facilitate digestion. These tissues were dried at 90° C. for 8 hours and their dry weights determined. Digestion was carried out by adding 20 ml. of concentrated nitric acid to the leaves and the mixture heated on a water bath for two hours. This treatment completely dissolved the tissues. Enough water was then added to bring the total volume again to 20 ml. An aliquot of 0.2 ml. was placed in the standard depression slide and heated at 56° C. until dry. Uniform films were thus obtained. Treatment of the urediospores was similar to that of the leaves with few modifications. Leaves of the 150 wheat seedlings were shaken over an evaporating dish and the urediospores collected by brushing them directly into drying dishes. After drying, the spores were found to be resistant to complete digestion with nitric acid, and aqua regia was used in its stead. Three such slides were made for each determination. All results recorded were obtained by averaging the counts from the three aliquots.

For the actual determinations a small Geiger tube, sensitive to beta rays, was mounted in a wooden frame so that when the slides were placed beneath it, the plane surface of the slide was 0.5 cm. from the tube. Twenty-minute background counts were made before each day's analyses, and all counts on the tissue digests were made for 10 minutes. Preliminary studies with longer exposures showed no gain in accuracy. Because radioactive phosphorus continuously and irrevocably disintegrates, corrections for the time interval between the clipping of the leaves and counting were made from a decay curve (5). The active phosphorus was recorded as counts per gram dry weight, to which it is directly proportional (5). All figures have been rounded off to the third digit, because in these analyses only differences in the first two digits were important.

To follow the changes in the distribution of phosphorus, radiographs (5) of the leaves were made every second or third day after inoculation of the seedlings. Fresh green leaves were mounted on glass plates with transparent cellulose tape, through which the beta rays from the P^{32} can pass. This type of mount was easy to handle and also preserved the leaf in a green condition for regular photographs. Verichrome film was placed against the mount, and it in turn was covered with a glass plate.

ABSORPTION AND DISTRIBUTION OF PHOSPHORUS

The infection of leaves of Little Club wheat with *Puccinia graminis tritici* does not appear to affect the total amount of phosphorus in the leaves.

TABLE 1.—*Concentration of radioactive phosphorus in inoculated and noninoculated leaves*

No. days after inoculation	Counts of radioactivity[a]	
	Inoculated leaves	Noninoculated leaves
2	16,400	22,100
5	24,500	17,800
10	22,300	21,300
Average	21,067	20,400

[a] Counts were recorded on the basis of counts per gram dry weight.

A comparison of the radioactive phosphorus in the whole leaves of inoculated and noninoculated plants reveals no consistent differences in the amount of that element (Table 1). When all replicates were averaged, however, a slightly greater concentration was found in the inoculated seedlings.

The total amount of phosphorus absorbed by the plant was not significantly influenced by the disease but its distribution within the leaf was affected. More phosphorus was present in the distal parts of all leaves than in the basal parts. The difference in concentration between the two parts of the leaf was, however, much greater in inoculated plants than in the check plants. This increased accumulation in the infected distal portion was consistently greater in all the replicates, even though the phosphorus determinations were made at intervals from the second to tenth day after inoculation. On the average, the difference in phosphorus counts between the distal and basal leaf sections were twice as great for the seedlings in which the upper part was infected as for the normal plants; the differences were 4,667 and 1,967, respectively (Table 2).

Because of the possible presence of extraneous radioelements which would confuse the results, analyses were made on leaves grown in the normal Hoagland's solution. No radioactivity was detected in these leaves. Therefore, all measured activity in the leaves was due to the beta rays emitted by the P^{32}.

To study the reason for the increased amount of phosphorus in the infected portion of the leaf, radiographs were made at various intervals of

TABLE 2.—*Distribution of radioactive phosphorus in leaves*

No. days after inoculation	Counts of radioactivity					
	Inoculated leaves[a]			Noninoculated leaves		
	Distal sections	Basal sections	Difference	Distal sections	Basal sections	Difference
2	18,700	14,100	4,600	23,400	20,700	2,700
5	27,000	22,100	4,900	18,500	17,300	1,200
12	24,500	20,000	4,500	22,300	20,300	2,000
Average	23,400	18,733	4,667	21,400	19,433	1,967

[a] Distal sections were infected with rust, basal sections were not infected.

time after inoculation. Film was exposed to leaves clipped from the plants just before inoculation and at 2, 4, 5, 6, 7, 8, 9, and 10 days after inoculation. Flecking was first observed on the fourth day, raised pustules on the eighth

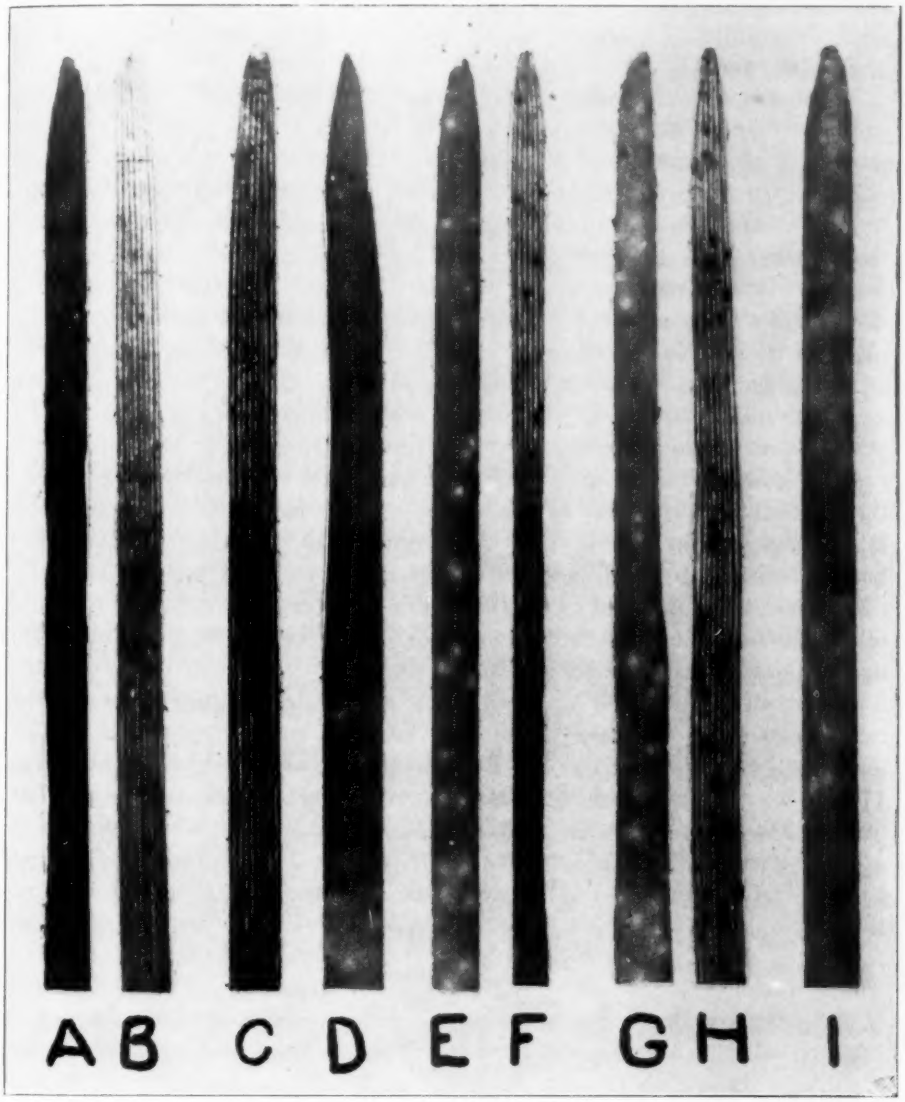

FIG. 1. Radiographs and photographs of *Puccinia graminis tritici* on Little Club wheat taken on various days after inoculation. A and B. Radiograph and photograph, 2nd day. C. Photograph, 4th day. D. Radiograph, 5th day. E and F. Radiograph and photograph, 6th day. G and H. Radiograph and photograph, 7th day. I. Radiograph, 8th day.

day, and sporulation on the ninth day after inoculation. In radiographs made on the second day after inoculation phosphorus was evenly distributed in the leaf. On the fourth day, coincident with the period when flecks were

becoming visible, differences in the density of the negative were observed. At this time the differences in density of these areas of the leaf were not sufficient for good reproduction. From then on, as the flecks became further differentiated, the density of the film in the infection court increased until the ninth day when the spores began to rupture the epidermis (Fig. 1, D, E, G, and I).

Photographs were made of the leaves that were exposed for the radiographs. Some of these are reproduced in figure 1, B, C, F, and H. A comparison of radiographs and photographs showed that the phosphorus is concentrated in the infected areas of the leaf. It is apparent then that rust infection stimulates the accumulation of radioactive phosphorus in the diseased areas of the plant. That the images of the leaves and infected areas are due to the radioactive phosphorus was demonstrated by placing two leaves side by side, one from a seedling in a nutrient solution containing radioactive phosphorus and the other containing normal phosphorus. Only the leaf containing the radioactive material affected the film and left an image on the negative. The entire series of plants for the radioactive studies were rerun and similar results were obtained.

The accumulation of unusually large quantities of phosphorus in the infection court might be due to two causes; either phosphorus is deposited in the urediospores or mycelium of the fungus, or in the infected cells of the host. Because of the difficulties in separating the host tissues from the mycelium of the parasite in quantity large enough for analysis, no determinations could be made on the components of this complex. However, the urediospores were collected and analyzed. Radiographs of the spores indicated the presence of P^{32}. The specific activity of phosphorus contained in the spores was less than the mean average of both infected portions of leaves and of entire healthy leaves. The specific activity of the spores was 17,200, for the entire noninoculated leaves it was 20,400, and for rusted leaves 21,067. We can assume, therefore, that the increased accumulation of phosphorus in the infected areas of the plant was not in spores but might be in infected host cells. Another possibility does still exist, namely, that the accumulation is in the mycelium of the rust.

DISCUSSION

The effect of *Puccinia graminis tritici* on the phosphorus distribution in infected wheat leaves is similar to the effect of rusts and mildews on the plant carbohydrates: in both cases the materials are concentrated in the invaded areas of infected leaves (3, 12). If studies from both obligate parasites, the rust and the mildew fungi, can be considered as complementary, a picture of some of the physiological responses in obligate parasitism can be reasonably formulated. The pathogen is dependent upon its host for carbohydrates. Any unfavorable conditions such as light, temperature, and nutrition, which prevent normal plant vigor and synthesis of carbohydrates, reduce the supply of sugars and also the virility of the pathogen

on its host. As a reaction to the increased nutritive demands of the parasite, sugars and phosphorus accumulate in the infected areas of the leaves. The augmented phosphorus supply might permit a greater activity of the phosphorylating enzymes of intermediary sugar metabolism. Thus the increased amount of carbohydrates would be consumed and respiration consequently increased. Eventually the demands upon the hosts cells are too drastic or some toxic action ensues, and necrosis occurs.

Unfortunately, it is not known whether the concentration of phosphorus and carbohydrates is in the fungus mycelium or in the host cells; in either case an increased respiration of the infected tissues would result. Humphrey and Dufrenoy (6) indicated that the mycelium receives its phosphorus from the invaded cells and that the spores are "rich in phosphorus." However, analyses of urediospores revealed no such undue accumulation, for less radioactive phosphorus per gram dry weight was found in the spores than in either infected or normal leaves. It is plausible to conclude that the concentration of phosphorus might be in the infected host cells. Whether the increased amount of phosphorus in rusted areas is due to a specific action of the parasite or is merely a general reaction of plant cells to injury and irritation is still undetermined. However, studies of injured animal tissue indicate that, even without the presence of a parasite, phosphorus compounds are sometimes secreted into the damaged areas (4). Yeast cells also secrete the phosphorus compounds when subject to mild irradiation with X-rays (8). Until further studies are made, any interpretation of the cause for the concentration of phosphorus in tissue infected by obligate parasites must be accepted with reservation.

SUMMARY

1. No consistent differences in total content of radiophosphorus were found between entire rusted and healthy wheat leaves.

2. In inoculated leaves the differences in phosphorus content between the infected distal portion and the noninfected basal portion of the leaves were much greater than the differences of similar areas in healthy plants. The distal parts always contained more phosphorus.

3. The phosphorus was accumulated in rusted parts of leaves and concentrated in the areas invaded by the parasite.

4. The concentration of radiophosphorus in the urediospores was less than in the leaves.

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DIPLODIA DIE-BACK OF GUAYULE (PARTHENIUM ARGENTATUM GRAY)

JOHN T. PRESLEY[1]

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INTRODUCTION

A die-back of guayule caused by *Diplodia theobromae* (*D. natalensis*) (Pat.) Nowell,[2] occurred in southern Texas during the summer of 1944, and was first observed following the summer rains. In two-year-old irrigated plantings, where the crowded condition of the plants favored the disease, practically every plant was infected and many plants were dead by mid-October. In dry-land plantings and in one-year-old irrigated plantings infections were few and there was relatively little damage from the disease.[3] Dry weather retarded the disease and during the winter fungus activity ceased entirely. With the return of high temperatures and rain in the spring of 1945 many of the old lesions again became active. In addition to the old lesions, the pycnidia which were produced in abundance on the diseased plants furnished abundant inoculum for new primary infections.

SYMPTOMS

Infection generally starts in the leaves or small twigs and progresses downward. In the field the leaf infections begin as irregular necrotic lesions which soon coalesce. The leaves die, generally from the tip, with pronounced yellowing of the leaf after one-half of the blade has been killed. Infections that begin on small twigs soon progress downward and involve the larger branches. When the lesion has nearly girdled a large branch the leaves become yellow and the diseased branch is very conspicuous among healthy foliage. As soon as the branch is completely girdled it dies (Fig. 1, C). When infection occurs near the ground line the entire plant succumbs as soon as it is girdled by the fungus lesion. After the plant or branch dies, provided moisture conditions are favorable, black pycnidia of the fungus develop under the diseased bark and erupt as elongated black carbonaceous masses (Fig. 1, D).

INOCULATIONS

Methods

Experiments were conducted at Salinas, California, to determine the effects of temperature, moisture, and age of plant on infection by *Diplodia*. Pycnidial material for the experiment was collected from diseased plants in Texas in October, 1944. A spore suspension was obtained by soaking

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[2] Specific determination of the organism was made by John A. Stevenson, Division of Mycology and Disease Survey, U. S. Department of Agriculture.

[3] Presley, John T. Diplodia die-back of guayule. U. S. Dept. Agr., Plant Dis. Reptr. 29: 64. 1945.

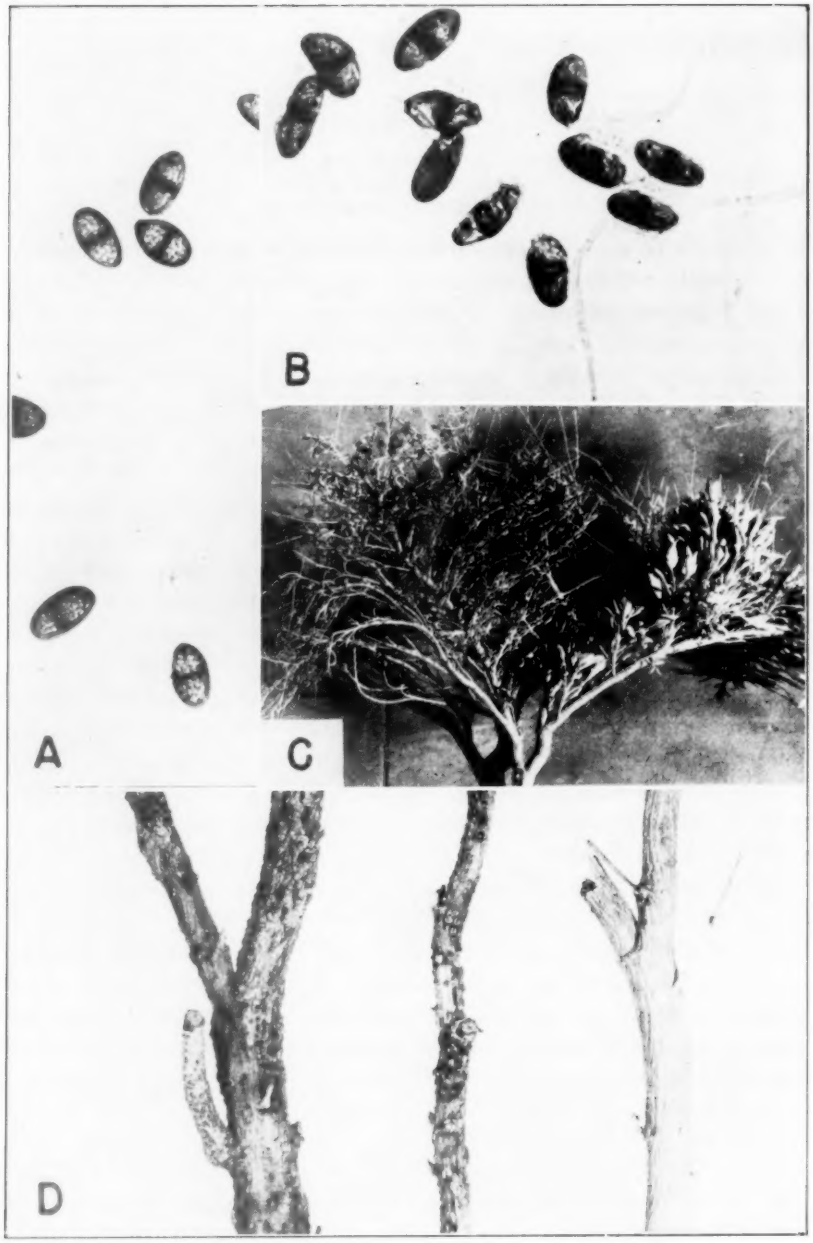

FIG. 1. *Diplodia theobromae*. A, spores; B, germinating spores; C, 2-year-old guayule plant with one diseased branch; and D, pycnidia on two diseased branches on left, healthy branch on right.

and agitating the pycnidial material in flasks of distilled water. The guayule plant material and seed used in the experiments were of the standard variety No. 593, and were placed in temperature tanks at the beginning of the experiment.

The first experiment consisted of three treatments: (1) Guayule seed, 100 in each pot, were planted in pots of pasteurized soil, and the soil surface sprayed with a suspension of Diplodia spores. (2) The leaves of transplanted nursery stock that had been permitted to grow for six weeks in 8-inch pots were punctured to simulate insect injury and sprayed with the spore suspension. (3) The noninjured leaves of similar transplanted nursery stock were sprayed with the spore suspension.

Plants of two different ages were used in the second experiment. The first consisted of transplanted nursery seedlings that had grown for eight weeks in the greenhouse and had reached the flowering stage, but with all of the leaves still green and active. The second consisted of older plants that had grown in pots outside the greenhouse for many months. These plants were in a hardened condition and had many dead leaves on the lower portions of the stems, and they were very similar to field-grown guayule.

All plants were sprayed with the spore suspension, placed in temperature tanks, and the containers covered to maintain a high relative humidity around the plants. The plants were then sprayed with tap water at one-hour intervals through the day to insure a film of water on the leaves. At the end of 24 hours four containers at each temperature had the covers removed. These and the covered plants were sprayed at intervals throughout the day with water to keep them moist. After 48 hours a second series of four covers was removed and all of the plants sprayed throughout the day as before. An additional series had the covers removed after 72 hours and 96 hours.

Three inoculated and one check plant for each treatment were used at each temperature, ranging from 50° to 100° F. in 10° increments. All plants were placed in the temperature tanks and allowed to stand for 12 hours for temperature adjustment before being sprayed with the spore suspension. A small hand sprayer was used and each plant was sprayed until thoroughly wet with the spore suspension. Subsequently the plants were watered as needed to keep them vigorous.

A germination test of the fungus spores proved them to be viable (Fig. 1, A and B). Dry slides covered with spores were placed in moist chambers where the humidity was maintained at 100 per cent; also, slides with spores in drops of distilled water were kept in moist chambers. The spores in the drops of water germinated after about four hours at room temperature (70° to 80°) (Fig. 1, B), but it required almost a full day for germination of the spores on the dry slides maintained at 100 per cent humidity.

Results

Experiment 1, Treatment 1. The plants began emerging after four days at 80° and 90° F., two to three days later at 60°, 70°, and 100°, and after two weeks in the 50° tank. Soon after emergence some of the seedlings at 70°, 80°, and 90° had symptoms of damping-off. Four seedlings damped-off at 70°, 4 at 80°, and 5 at 90° F. *Diplodia* was isolated from all the diseased

seedlings. Counts of emerged seedlings after 14 days at the various temperatures demonstrated that *Diplodia* caused appreciable loss only at 80° F. (Table 1).

Experiment 1, Treatments 2 and 3. Three days after being sprayed with the spore suspension there was no apparent infection of the plants at any temperature. These plants were again sprayed with the spore suspension on March 10 and half of the plants in both treatments were covered in order to hold the humidity at a high level and prevent drying of the film of water on the leaves. On March 12 some of the covered plants at 80°, 90°, and 100° F. had symptoms of Diplodia infection on the leaves and small twigs.

Isolations were made from the visibly infected twigs and *Diplodia* was recovered from all of the platings. Isolations were also attempted from twigs without visible infection symptoms. For all of these platings, a por-

TABLE 1.—*Emerged guayule seedlings after 14 days in soil infested with Diplodia, at various temperatures*

Soil temperature	Emerged seedlings, inoculated soil	Check
	Average of 3 replicates	
Degrees F.	*Number*	*Number*
50	12	16
60	47	41
70	39	46
80	26	43
90	29	31
100	16	16

tion of the twigs was surface sterilized for two minutes in commercial Clorox, full strength; the remaining portion was not surface sterilized but was washed thoroughly in distilled water and plated. In the higher temperature series, *Diplodia* was recovered from both surface-sterilized and non-surface-sterilized material, indicating that the fungus had penetrated the plant tissue. *Diplodia* was recovered from the non-surface-sterilized but not from the surface-sterilized material at 50° F., indicating that inoculum was present in a viable condition, but the temperature was not favorable for infection to take place. There appeared to be no difference in amount of infection between treatment 2 and treatment 3. This test established the pathogenicity of *Diplodia* on guayule at certain temperatures, hence an additional test was needed to establish the moisture-time relationship of the infection.

Experiment 2. Final observations were made on March 26 (six days after spore suspension was applied) and photographs taken of the plants that had been covered for 48 hours (Fig. 2). The results at the various temperatures are given in table 2.

Plants from the 100° F. tanks were not included in the photographs because of the complete break-down of the leaves on both young and old plants at that temperature when covered for two days or more. The high humidity

and high temperature acting together apparently were responsible for the break-down. In the first experiment the uncovered check plants at 100° F. survived, hence the covering at 100° seems to have had some effect other than aiding fungus penetration.

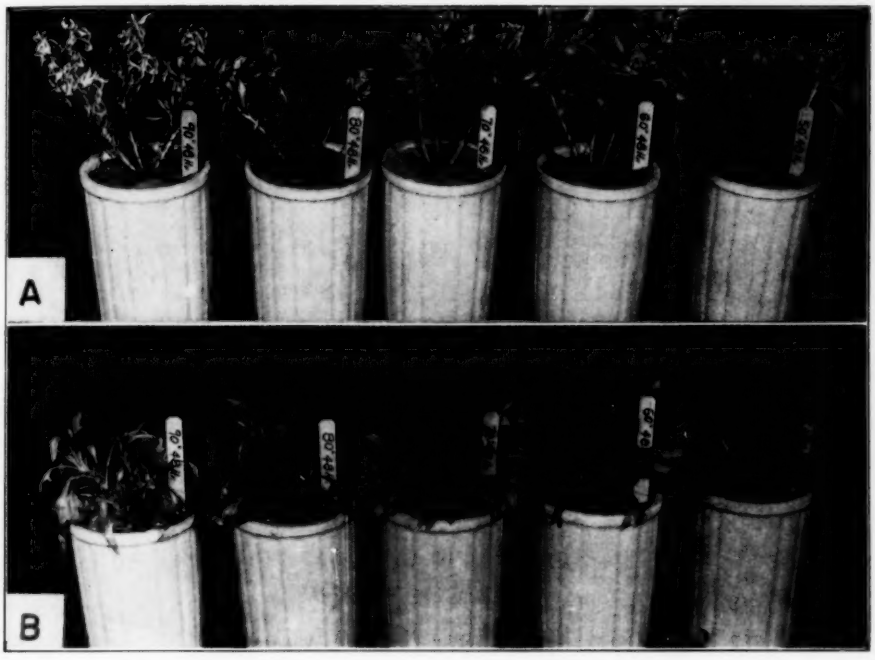

FIG. 2. Guayule inoculated with *Diplodia theobromae*. A, effect of induced disease on hardened plants at indicated temperatures and time intervals. B, effect of inoculations on young succulent plants at indicated temperatures and time intervals.

DISCUSSION

The inoculation tests established the fact that a high relative humidity and high air temperatures are necessary for rapid infection by *Diplodia*. Infection takes place more quickly in older hardened plants than in younger vigorously growing plants. Dead leaves on the plants definitely favor infection, perhaps because the fungus grows saprophytically for a time on the dead leaves and then penetrates the green tissue. The rate of decline of infected plants is also markedly influenced by temperature and humidity. At all temperatures up to and including 90° F. there was no apparent fungus injury to the plants during the first 24-hour period when they were covered. At 48 hours and subsequently, there was definite fungus injury at temperatures above 60°; hence it may be concluded that in an area such as south Texas during the rainy period in late summer when temperatures are high, the rains frequent, and the relative humidity high, infection by *Diplodia* will take place. Optimum conditions for infection do not occur every summer as evidenced by the fact that guayule plantings had been in south Texas

TABLE 2.—*Infection of guayule plants by Diplodia as influenced by humidity at various temperatures*

Days covered	Temperature	Young plants	Old plants
No.	°*F.*		
1	50	No visible symptom	No visible symptom
2		do	do
3		do	do
4		do	do
1	60	do	do
2		do	do
3		do	Slight damage to older leaves
4		do	Tips of healthy leaves slightly affected and older leaves more so
1	70	do	Slight damage to healthy leaves
2		do	Pronounced damage to the leaves and some twig infection
3		Necrotic areas on most of the lower leaves	Pronounced damage to the leaves and some twig infection
4		Necrotic areas on most of the lower leaves	Pronounced damage to the leaves and some twig infection
1	80	No visible symptom	No visible symptom
2		Slight necrosis on lower leaves	Definite infection of stems and pronounced damage to the leaves
3		Pronounced necrosis on lower leaves	1 plant dead and 1 partly dead
4		Practically all leaves severely affected and dying	1 plant dead and 1 partly dead
1	90	Slight necrosis of lower leaves	No visible symptom
2		Necrosis more pronounced	1 plant completely dead, 1 partly dead
3		Rather general infection of leaves except at growing tip of plant	Both plants dead
4		1 plant dead, other severely affected, most of the leaves dead	1 plant dead, other severely affected
1	100	1 plant very slightly necrotic, other severely damaged	Few dead twigs and extensive leaf injury
2[a]		All leaves dead when uncovered	Plants severely affected, many twigs dead
3		All leaves dead when uncovered	Both plants dead
4		All leaves dead when uncovered	Both plants dead

[a] The complete breakdown of the leaves on both old and young plants when covered for 2 days or more at 100° apparently resulted from factors other than fungus invasion.

more than two years before an outbreak of *Diplodia* of sufficient severity to cause appreciable damage was recognized.

The closely related species *Parthenium incanum* H.B.K., known as mariola, is also susceptible to *Diplodia*. The infection was evidenced by pronounced spotting of the leaves but no branches or twigs were killed on the plants inoculated. It may be assumed that under the conditions of the experiment mariola is less susceptible to Diplodia infection than guayule.

SUMMARY

Diplodia theobromae caused a severe die-back of 2-year-old irrigated guayule in south Texas in late summer and early fall of 1944. Younger

irrigated shrub and 2-year-old shrub on dry-land plantings were not appreciably affected.

Inoculation experiments demonstrated that spores in the soil could cause the loss of small seedlings, especially at 80° F. Leaf and twig infections in the greenhouse were dependent upon high humidity for 24 or more hours and temperatures of from 80° to 90° F. Hardened plants with old dry leaves were more susceptible to infection than young succulent plants with green active leaves.

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PHYTOPATHOLOGICAL NOTE

Copper 8-Quinolinolate, a Promising Fungicide.—Preliminary laboratory and field tests have indicated the possible use of an organic compound for the control of plant diseases. In glass-slide fungicide tests the compound 8-quinolinol and its copper derivative were both highly toxic to *Sclerotinia fructicola,* having an L.D.50 range of less than 1.5 micrograms per sq. cm. of glass slide. Chlorine substitution on the 5 and 7 positions of these parent compounds decreased toxicity to an L.D.50 of 50 and 200 micrograms per sq. cm. of glass slide, respectively, while bromine substitutions in the same positions decreased toxicity to an L.D.50 of 400 and 1200 micrograms, respectively.

In 1945 these materials were used in field tests for the control of apple scab and blotch. Other materials used for comparison were Puratized N5–E (10 per cent phenyl mercuri triethanol ammonium lactate), Isothan Q 15 (20 per cent lauryl isoquinolinium bromide), Isothan Q 32 (20 per cent cetyl isoquinolinium bromide), and Fermate (ferric dimethyldithiocarbamate).

A 30-year-old block of Duchess apple trees was divided into single-tree blocks with three single-tree replications per treatment. Spray applications were made on April 27, May 9 and 23, June 1, 11, and 22, and July 11. The first spray, April 27, was at the early bloom period and contained only the respective fungicide treatments. The five succeeding applications contained the fungicide plus 3 lb. of lead arsenate and 3 lb. of hydrated lime to 100 gallons of water, except that lime was omitted from sprays containing Fermate. Fermate in itself is an arsenical safener. The other fungicide treatments are not known to be arsenical correctives, thus lime was added whenever lead arsenate was used with them. The last application on July 11, contained only the fungicide treatment. The amount of each fungicide used to 100 gallons of spray is shown in table 1. Final fruit records were taken on July 25 (Table 1).

Although 8-quinolinol and its copper derivative were both highly toxic in the laboratory, the former did not retain its toxicity in the field and was the least effective of the six materials tested. This might possibly be explained by its higher solubility in water, which would prevent less residual toxicity to be retained. The copper content of the latter may have increased its effectiveness in the field over the parent compound. Copper 8-quinolinolate, was highly fungicidal and compared favorably with Fermate and Puratized N5–E in controlling scab and blotch. Commercial control was not secured with Isothan Q 15 and Q 32.

Under the conditions of the trial there was no visible fruit or foliage injury from any of the six materials tested. Fruit analysis (Table 1) of acid and soluble solids indicated that the fungicidal treatment affected indirectly the maturation. This fruit maturation difference was apparently directly correlated with fungus infection in that the more severe the infection, or the less the control, the higher was the degree of maturation.

TABLE 1.—*Efficacy of 8-quinolinol and its copper derivative in the control of scab and blotch on Duchess apple in 1945*

Treatment	Amount to 100 gal. of water	Fruit analyses			Percentage of fruit infected	
		Per cent acid	Per cent soluble solids	Degree of maturation[a]	Scab	Blotch
Fermate	1 lb.	1.38	8.7	M 2	37.8	0.1
Cu 8-quinolinolate	1 lb.	1.31	8.7	M 3	17.3	0.7
Puratized N5–E	½ pt.	1.50	8.7	M 1	11.1	7.9
Isothan Q 15	1 pt.	1.31	9.4	M 3	38.9	54.0
Isothan Q 32	1 pt.	1.32	10.0	M 3	42.3	66.1
8-quinolinol	1 lb.	1.20	9.3	M 4	40.7	86.2

[a] M 1, M 2, M 3, M 4 = advancing degrees of maturation.

The compound copper 8-quinlinolate shows considerable promise as a protectant for apple scab and blotch.

The writer wishes to express appreciation to Dr. R. V. Lott, Associate Professor of Pomology in the Department for making the fruit analyses.—
DWIGHT POWELL, University of Illinois, Urbana, Illinois.

REPORT OF THE 37TH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The American Phytopathological Society held its 37th annual meeting with the American Association for the Advancement of Science in St. Louis, Missouri, March 27–30, 1946. The sectional and business sessions were held in the Jefferson and Statler hotels. Approximately 325 members attended. Eighty-six papers on original research were accepted by the editorial committee for presentation at the meeting. The sections and number of papers presented in each follow: fungicides, 11; small grain diseases, 10; viruses, 13; vegetable diseases, 10; physiology of pathogenic fungi, 9; cereal diseases and pathogens, 10; disease resistance and genetics, 9; forest pathology, 5; factors affecting disease resistance, 6; and 3 in the joint session with the Mycological Society of America.

Conferences included "Plant Disease Survey," "Extension," "Fungicides," "Late Blight of Potato," and a meeting of the Tobacco Disease Council.

The Phytopathologists' dinner, held in the Missouri room of the Hotel Statler on Thursday evening, March 28, was attended by two hundred and twenty.

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Reorganization of International Cooperation. H. P. BARSS, G. H. COONS, J. G. HARRAR, OTTO REINKING, J. A. STEVENSON, E. C. STAKMAN, Chm.

Standardization of Fungicidal Tests. M. C. GOLDSWORTHY, C. S. HOLTON, J. G. HORSFALL, M. B. MOORE, C. F. TAYLOR, H. W. THURSTON, J. D. WILSON, S. E. A. MCCALLAN, Chm.

Terminology (Nomenclature) of Immunology and Use of Technical Words. D. L. BAILEY, W. H. BURKHOLDER, DONALD FOLSOM, M. W. GARDNER, Chm.

War Committee. J. G. LEACH, E. C. STAKMAN, I. E. MELHUS, Chm. (Executive Committee).

Coordination of Field Tests with New Fungicidal Dusts and Sprays. J. D. WILSON, Chm. (Committee to be announced).

Temporary Committees for 1945:

Auditing. J. RALPH SHAY, R. W. SAMSON, Chm.

Resolutions. C. T. GREGORY, H. C. MURPHY, C. M. TUCKER, Chm.

Temporary Committees for 1946:

Publication of Special Material. H. P. BARSS, J. G. LEACH, W. H. TISDALE, DONALD CATION, Chm.

Sustaining Contributors. R. J. HASKELL, F. L. HOWARD, J. J. CHRISTENSEN, Chm.

Report of the Secretary. At the time of the last Council meeting on December 11, 1944, in Cincinnati, Ohio, the membership was 1089. On December 31, 1945, the total was 1100, a net gain of 11 members. Included in the 1100 were 38 new members and 46 reinstatements. During the period from December 11, 1944, to December 31, 1945, the Society lost 73 members: 9 by resignation, 9 by death, and 55 suspended for non-payment of dues.

Ninety-three names were presented to the Society for membership, 39 of whom applied in 1945 and 54 in 1946; thus the total membership after the election on March 30 was 1193. The 39 applying in 1945 will be placed in the 1945 report, while the 54 applying in 1946 will be included in the totals for that year.

Report of the Treasurer. Statement of accounts for the year ending September 30, 1945.

Receipts:

Balance from 1944			$2016.34
Annual dues:			
1944	$ 58.00		
1945	4731.33		
1946	104.00	$4893.33	
30-Year Index		5.50	
Sales		42.41	
Sustaining contributors		200.00	
Unclassified receipt		114.25	
Total receipts			5255.49
			$7271.83

Expenditures:

Member subscriptions transferred to PHYTOPATHOLOGY:		
1944	$ 46.40	
1945	3772.35	
1946	82.20	$3900.95
Transferred to PHYTOPATHOLOGY for:		
Sales:		
Phytopathology	43.41	
30-Year Index	5.50	48.91
Secretarial work and expenses, Office of Secretary		218.28
do , Office of President		56.08
do , Office of Treasurer		275.75
Printing and stamped envelopes		295.46
Stamps		6.00
Money returned for overpayment of dues		16.00
Bank charge		1.95
Exchange charge		.85
Donation to Union of American Biological Societies		50.00
Annual meeting expenses		23.53
Total expenditures		$4893.76
Balance on hand Sept. 30, 1945		2378.07
		$7271.83

Sinking Fund. Arlington and Fairfax Building and Loan Certificate No. R–1423 for 10 shares (value $1000) transferred to Arlington and Fairfax Building and Loan Association Savings Share, Account Certificate No. 70 (value $1000) January 1, 1945. There was no change in the principle amount of the sinking fund during the past year, the total remaining $9676.00. It is invested as follows:

First mortgage note, at 4½ per cent interest, deposited with McLachlen Banking Corporation for collection	$ 500.00
U. S. Savings Bond, Series G, 2½ per cent	1000.00
Invested with the following:	
Columbia Permanent Building Association (accrued dividends $52.10)	552.10
District Building and Loan Association (accrued dividends $152.29)	1652.29
National Permanent Building Association (accrued dividends $263.30)	2263.30
Northwestern Federal Savings and Loan Association	2000.00
Perpetual Building Association (accrued dividends $104.20)	1104.20
Prudential Building Association (accrued dividends $26.41)	202.41
Arlington and Fairfax Building and Loan (accrued dividends $15.00)	1015.00
	$10289.30
Less interest due PHYTOPATHOLOGY	613.30
	$ 9676.00

The Lyman Memorial Fund, obtained from voluntary contributions, now totals $3195.82. The whole amount is invested with the Brookland Building and Loan Association, at 2½ per cent. The account for 1945 is as follows:

Balance on hand, Oct. 1, 1944	$3384.85
Dividends, Dec. 31, 1944 to June 30, 1945	94.01
Voluntary contributions	20.00
Memoir	.50
	$3499.36
Less interest due PHYTOPATHOLOGY	303.54
	$3195.82

Additional Endowment:

War Savings Bond, Series F	
Total, Sept. 30, 1944	$1050.00
Received Oct. 1, 1944 to Sept. 30, 1945	50.00
War Savings Stamps	
Total, Sept. 30, 1945	7.00
	$1107.00

Report of the Business Manager. The total number of nonmember subscribers was 554 on November 30, 1945, representing a net gain of 71 for the year 1945. These consisted of 338 domestic, 32 Canadian, and 184 foreign subscribers. Included in the domestic subscriptions for later foreign shipment are 30 for the Chinese Ministry, 44 for the USSR, and 7 for The Netherlands; also 3 complimentary domestic subscriptions. There were 31 subscription cancellations and suspensions in 1945. Not included in the reported subscriptions for 1945 are 55 subscriptions for the current volume, number 35, by the American Library Association, to be held by the Society for eventual shipment to foreign countries as may be designated by that association.

The sales of back volumes and issues during 1945 totaled $1409.70. This included, among the larger orders, amounts of $207.00 from West African Cacao Research Institute, Tafo, Gold Coast, and $208.30 from the Acme Agency, Buenos Aires, Argentina.

Statement of accounts for the year ending September 30, 1945.

Receipts:

Balance from 1944			$ 6372.55
Subscriptions			
1944	$ 36.35		
1945	2924.73		
1946	264.20		
1947	27.50	$3252.78	
Member subscriptions:			
1944	46.40		
1945	3772.35		
1946	82.20	3900.95	
Sales of back numbers of PHYTOPATHOLOGY		1409.70	
Sale of Membership List		1.00	
Advertising			
1944	327.61		
1945	807.18		
Membership List	275.00	1409.79	
30-Year Index		105.00	
Interest on Sinking Fund			
First mortgage	21.50		
Building and Loan	80.00		
U. S. Bond Series G	25.00	126.50	
Interest on current funds		145.08	
Grant from Rockefeller Institute		600.00	
Allowance on reprints		367.17	
From authors for excess illustrations		160.44	
Total receipts			11478.41
			$17850.96

Expenditures:

Printing, distributing, and storing PHYTOPATHOLOGY:			
Vol. 34, no. 9	$708.93		
10	680.40		
11	532.24		
12	733.09		
Vol. 34, Index	203.94		
Vol. 35, no. 1	745.42		
2	493.24		
3	581.06		
4	507.50		
5	731.06		
6	922.62		
7	716.65		
8	665.37	$8221.52	
Postage, PHYTOPATHOLOGY		404.17	$8625.69
Secretarial work and office expense, Editor-in-Chief			741.62
do , Advertising Manager			101.73
Postage for Advertising Manager			5.49
Commission for Advertising Manager (1944)			150.00
Expenses of Advertising Manager			19.12
Secretarial work for Business Manager			314.25
Stamps			7.00
Printing and stamped envelopes			184.62

Office supplies	19.75	
Miscellaneous	33.60	
Postage, 30-Year Index	8.36	
Refund, subscription and sales	31.20	
Bank charges	1.60	
Printing Membership List	276.02	
Checks returned by bank	12.00	
Total expenditures		$10532.05
Balance on hand:		
Checking account	2374.14	
Northwestern Federal Savings and Loan	4944.77	7318.91
		$17850.96

The 30-Year Index. Summary of receipts and expenditures October 1, 1944 to September 30, 1945:

Balance in excess of expenditures, Sept. 30, 1944	$118.48
Receipts Oct. 1, 1944, to Sept. 30, 1945	105.00
	$223.48
Expenses Oct. 1, 1944, to Sept. 30, 1945	8.36
Balance in excess of expenditures, Sept. 30, 1945	$215.12

Membership List Account, 1944–1945.

Receipts for advertising		$324.98
Printing, 1500 copies	$268.02	
Postage for mailing	8.00	276.02
		$ 48.96
Membership lists sold		1.00
Balance on hand, Sept. 30, 1945		$ 49.96

Report of the Auditing Committee, as of September 30, 1945. We have examined the books of the Treasurer of the American Phytopathological Society and of the Business Manager of Phytopathology for the period October 1, 1944, to September 30, 1945, and find all funds, receipts, and expenditures of the Society and of PHYTOPATHOLOGY properly and clearly recorded and accounted for. Much credit is due Miss Melba K. House for the excellent state of the books.

Signed: R. W. SAMSON, *Chairman*
J. RALPH SHAY

Report of the Advertising Manager. PHYTOPATHOLOGY carried a total of 95 paid subscriptions during the year 1945. There were 52 full-page, 32 half-page, and 10 quarter-page advertisements.

The gross income from advertising was $1255.00. The net income to the Society will appear in the Treasurer's report. Advertising agencies get a 15 per cent commission, and a 2 per cent discount is allowed when bills are paid within 10 days. This accounts for the difference between the gross and the net income.

In addition to paid advertisements, the Journal has carried 1 full-page, 9 half-page, and 10 quarter-page announcements for the Society in the advertising section.

The present advertising manager wishes to express his appreciation of the fine help and cooperation of the previous advertising manager, S. L. Hopperstead.

Report of the Editor-in-Chief. Two hundred and two individuals utilized the 1032 pages of volume 35 of PHYTOPATHOLOGY to publish 100 articles, 34 notes, 39 abstracts, and 7 biographies. The volume contained 216 text figures and 7 portraits; and tabular material constituted 11.5 per cent of the 975 pages utilized for scientific papers. Three reports and three announcements were published for the Society in the volume.

On March 1, 1946, there were 64 papers on hand: 22 have been accepted for publication, 17 are being revised by the authors, and 25 are under consideration by the editorial board. Between January 1, 1945, and March 1, 1946, seven papers have been withdrawn or rejected.

A manual on "Preparation of manuscripts for Phytopathology" has been written by Dr. A. J. Riker, a member of the editorial board. The American Phytopathological

Society authorized the manual at its meeting in Cincinnati, Ohio, in December, 1944. Publication is planned for 1946.

The editor is pleased to acknowledge the financial assistance given PHYTOPATHOLOGY in 1944 and 1945 by the Rockefeller Institute for Medical Research.

Every member of the Editorial Board has cooperated in reviewing manuscripts submitted for publication: the work of the editorial office would have been impossible without their assistance. It is also a pleasure to acknowledge the advice and help of the Science Press Printing Company in meeting the difficulties besetting scientific publications during war times.

Report of Society Representative on the National Research Council for 1945. Activity of the Division of Biology and Agriculture during the year may be summarized with respect to matters related to our field as follows:

1. The Division has been active in keeping representatives informed as to the progress of the bills before Congress concerned with a National Research Foundation and bringing its influence to bear on the need of proper emphasis upon research in biology in the formulation of this legislation. At your president's request a statement was prepared by your representative which was filed with the appropriate Committee of Congress.

2. A Microbiological Board within the Division was recommended to function as a central clearing and guidance agency in this field. Particular interest at the moment is concerned with antibiotics which obviously reaches into the field of plant disease control. While such a board has not as yet been set up, preliminary conferences have been held to consider organization and the possibilities of financial support for such organization.

3. The Office of Scientific Personnel continues to function with financial support by the American Institute of Physics, the American Mathematical Society and the Mathematical Association of America, the Geological Society of America, and the newly formed American Psychological Association. During the war, Biology was represented financially by a special grant from the National Academy ($3000). At present biological societies are not contributing to this central effort.

4. The Committee on the Training of Research Workers in Agriculture is making a careful study of the needs of fellowships in this field. If the Fellowship program included in the National Research Foundation legislation does not materialize, it is expected that efforts will be made by the Division to initiate a strong fellowship program in Agriculture.

Report of the Representative to the Board of Editors, American Journal of Botany. During 1945 this representative reviewed, at the request of the Editor-in-Chief, four papers dealing with subjects of phytopathological interest submitted for publication in the American Journal of Botany. Three of these papers have already appeared in that journal. In two instances the names of well-qualified reviewers have been suggested to the Editor-in-Chief for papers dealing with plant diseases or plant-disease fungi.

This relationship with the American Journal of Botany has been a pleasant one and it is sincerely hoped that the suggestions for improvement of the papers examined have been of value.

Report of the Necrology Committee. Death date of member not previously reported:

JAMES IRA P. MCMURPHY, November 2, 1943

Deaths of members during 1945:

J. P. JOLIVETTE, February 2
A. E. EDGECOMBE, March 30
L. R. JONES, April 1
M. B. WAITE, June 5
L. H. LEONIAN, June 7
C. J. KING, October 17
R. B. HARVEY, November 4

Report of the Manager of Phytopathological Classics. Report for the fiscal year beginning October 1, 1944, and ending September 30, 1945:

Classic No. 1:	On hand, Oct. 1, 1944	15	
	Sold during year	9	$ 4.50
	On hand, Sept. 30, 1945	6	
Classic No. 2:	On hand, Oct. 1, 1944	216	
	Sold during year	8	4.00
	On hand, Sept. 30, 1945	208	
Classic No. 3:	On hand, Oct. 1, 1944	306	
	Sold during year	8	4.00
	On hand, Sept. 30, 1945	298	

Classic No. 4:	On hand, Oct. 1, 1944	366	
	Sold during year	7	5.25
	On hand, Sept. 30, 1945	359	
Classic No. 5:	On hand, Oct. 1, 1944	604	
	Sold during year	10	12.50
	On hand, Sept. 30, 1945	594	
Classic No. 6:	On hand, Oct. 1, 1944	692	
	Sold during year	11	8.25
	On hand, Sept. 30, 1945	681	
Classic No. 7:	On hand, Oct. 1, 1944	716	
	Sold during year	14	10.50
	On hand, Sept. 30, 1945	702	
			$49.00

Value of books sent out (fiscal year 1944–1945)	$49.00
Overpayment (retained as credit)	.25
Money received on order of previous year	.75
	$50.00

Money received during fiscal year 1944–1945	$44.50
Gratis set of Classics for Editorial use (L. C. Knorr)	5.00
Due on account	.50
	$50.00

Assets:	
Cash balance on hand, Oct. 1, 1944	$463.03
Receipts during year	44.50
Total	$507.53
Liabilities:	
Error in financial records inherited from previous years	10.00
Balance on hand, Sept. 30, 1944	$497.53
Total due on account, Sept. 30, 1945	$ 20.25

Your attention is called to the fact that there remained only 6 copies of Phytopathological Classic No. 1 on September 30, 1945, and this classic is now out of print. Since most orders received are for complete sets, it behooves us to consider the advisability of reprinting this Classic No. 1. A second edition of 500 copies would probably meet our needs for several decades, and would allow our future customers to buy and maintain a complete set of Phytopathological Classics.

Report of Placement Committee. The Placement Committee has had the busiest year since the employment agency was established. This came about as a result of an unprecedented demand for plant pathologists and the return of veterans from the armed forces.

During 1945, fifty-two plant pathologists had applications filed with the committee. One hundred and fifty-five applications were sent to prospective employers who referred thirty-nine positions to the committee.

Incomplete records show that at least six plant pathologists obtained positions through the efforts of the Placement Committee.

Report of the Public Relations Committee for 1945. The reconstituted Committee has adopted a new means for acquainting the lay public with phytopathological progress by issuing its "IDEAS for Stories Featuring the Conquest of Plant Disease through Modern Research." Each "IDEA" is a brief synopsis that may be developed into a feature article. "IDEAS" are sent, a few at a time, to editors of 90 leading national magazines. If an editor is interested in the development of an "IDEA," the matter is referred to a specialist in that place of phytopathology, who prepares the article to meet the editor's specifications. The editor is obligated to permit the scientist who provides the material to check the completed article for scientific accuracy, and to reimburse the scientist at his customary rate.

During the year, 31 "IDEAS" were issued. More than half of these were selected as bases for feature stories by editors of Successful Farming, Fortune, Scientific

Monthly, Southern Agriculturist, Food Packer, and other magazines. The remaining "IDEAS," those not preempted by national magazines, were distributed to a key man in each State for issuance to newspapers and radio stations. Many congratulatory letters testify to the extensive use of these releases. The Committee is now represented on the editorial staff of the Scientific Monthly.

The work of the Committee has been self-supporting. The committee members were requested to contribute to the work of the Committee 10 per cent of amounts received for published articles, and the proceeds have been somewhat more than enough to pay the out-of-pocket expense of the Committee—stationery and postage.

The Committee takes this opportunity of thanking those members of the Society who have cooperated in the public relations work during 1945, either by assisting the Committee directly or through their free-lance efforts to the same end. For the future, "IDEAS" submitted by any member of the Society will be most welcome and will materially aid the work of the Committee.

Report of the Committee on Biological Abstracts and the Union of Biological Societies. *Two Decades.*—Twenty years ago a Joint Publications Committee, representing the National Academy of Sciences, Union of American Biological Societies, and American Association for the Advancement of Science, laid firm the foundations of Biological Abstracts. Nineteen volumes, comprising abstracts of some 425,000 contributions to research, have now been published—a significant accomplishment in itself. More important, however, is the fact that an agency for abstracting the entire world's output in biology was set going and has now been put on a secure footing for steady and rapid expansion in the years to come. This agency has also taken the initiative in establishing a world-wide system of cooperation among biologists. With more than 3,000 collaborators active in preparing and editing its material, Biological Abstracts has become one of the largest cooperative enterprises ever instituted by a scientific group. Plans for sectional publication have also been developed which represent a successful enterprise between institutional and specialized individual needs. Last year a new section—Abstracts of Human Biology—was added to the seven already in operation.

During the 1926–35 period, organization of the enterprise was made possible by large foundation subsidies. The difficulties of the succeeding transition period are now so well known among biologists as to require no summary here; suffice it to say that Biological Abstracts has weathered the storm, it stands on its own feet, its revenues have been built up to a point where continuance on a sound financial basis seems fully assured. Annual budgets have increased from $40,000 in 1938 to $89,000 in 1945. This reflects a steady healthy growth based in the main on increases in earned income—a growth controlled through appreciation of the service by the scientists themselves as reflected in their increasing subscriptions and support in other ways.

One Year. In the full edition of volume 19 (1945), 23,446 abstracts were published. At the beginning of 1945 the regular coverage included 1,900 periodicals. During the year it had increased to some 2,130, many of the later additions being European journals which had been unavailable through the war years. In 1945 some 444 new subscribers were added. An operational surplus of about $5,000 was reported, made possible by contributions including $13,655 from the industries, continuance of which cannot be counted upon. The cost of producing Biological Abstracts has more than doubled within the past four or five years. Salaries have had to be increased, and every phase of operation is costing more. A slight increase for subscriptions to the complete edition was thus made necessary, but the price of Section D (Phytopathology, Plant Physiology, Plant Anatomy, Paleobotany, Systematic Botany, Agronomy, Horticulture, Forestry, Pharmacognosy, Pharmaceutical Botany, and Ecology) remains the same—only $6.00 (foreign $6.50).

Plant Sciences. In Section D, Abstracts of Plant Sciences, approximately 5,500 abstracts were published during 1945; 883 of these were in the subsection on plant pathology, and 275 further abstracts containing at least incidental contributions on plant diseases appeared in other sections, making a grand total of 1,158. Subscribers to Section D increased by 96 during the year; of these some 25 were in response to the letter sent by this Committee to members of the American Phytopathological Society. It might be added that about 30 new subscribers resulted from a similar letter sent out to members of the Botanical Society of America by its Secretary.

Some time ago this Committee endeavored to establish a subsection for reviews of films dealing with plant diseases and pests. Much interest in the idea was shown in correspondence with research people and college and extension teachers. No one during the war, however, seemed to have the necessary time to implement the proposal. A comparable subsection established by the bacteriological groups has already proved its worth in their several fields of interest. The Editor of Biological Abstracts would like to see a section established for reviewing films of interest to the whole biological field. It is believed that teachers, extension workers, and researchers would benefit from such a

section. The Committee therefore recommends that the Society accept the responsibility of reviewing for Biological Abstracts films relating to plant pathology, perhaps through its Extension Committee.

The Future. It is hardly too much to say that the greatest impediment to the advancement of science is the lack of fully effective means by which the findings of the scientists themselves, and especially those of other nations, can be mobilized, brought to light, and put to work. Progress in carrying out the postwar plans for a more adequate and worldwide coverage will depend largely on how far the users of Biological Abstracts are willing to go in concrete acknowledgment of its value, through a steady increase in the number who subscribe. Biological Abstracts enters its third decade firmly established and willing and eager to give to scientists what they want and are willing to pay for; it is their cooperative enterprise.

Report of the Committee on Resolutions. Be it resolved that The American Phytopathological Society express its grateful appreciation to the following for their contributions to the success of the 37th annual meeting:

W. D. Valleau and Stephen Diachun for their arrangement of the section programs.

Carroll W. Dodge for arranging the musical program for the Society dinner, and his general assistance as the Society's local representative.

J. M. Hutzel, Executive Assistant A.A.A.S., for his helpful cooperation in assigning rooms and providing projection equipment.

The management of the Statler and Jefferson Hotels, particularly Mr. Bush of the Hotel Statler and Mr. Lucy of the Hotel Jefferson, for their assistance and courtesies in making their facilities available.

The newspapers—the St. Louis Post-Dispatch, the St. Louis Globe-Democrat, and the St. Louis Star-Times—for their effective handling of news coverage.

Respectfully submitted,
C. T. GREGORY
H. C. MURPHY
C. M. TUCKER, *Chairman*

Elections and Appointments. A committee from the Council opened and counted the ballots, results of which were announced to the Society at the banquet the evening of March 28: J. H. Craigie, President; A. J. Riker, Vice-President; C. M. Tucker, Councilor-at-large.

The Council recommended and the Society approved the appointment of Helen Hart as Editor-in-Chief for a three-year term, 1946 through 1948; W. H. Burkholder, Editor for a three-year term, 1946 through 1948; Donald E. Bliss, H. Loran Blood, A. L. Harrison, and Ray R. Hirt, Associate Editors for a three-year term, 1946 through 1948; Paul E. Tilford, Advertising Manager of Phytopathology for a one-year term; L. C. Knorr, Editor for Phytopathological Classics for a one-year term; John Niederhauser, Business Manager of Phytopathological Classics for a one-year term.

Representatives of the Society, new committees, and changes in committee personnel are given on the previous pages of this report.

Ninety-three applicants were elected to membership in The American Phytopathological Society.

Reports of Officers, Representatives, and Standing Committees are published on the previous pages. According to action of the Society at the Philadelphia meeting, reports of Special and Temporary Committees are not to be published in the annual report. All committee reports submitted were considered by the Council. The reports recommended for approval by the Council were accepted by the Society.

The Society approved the following recommendations by the Council.

1. That the paper entitled "Preparation of Manuscripts for Phytopathology," mentioned in the report of the Committee on Publication Problems and prepared in accord with the instructions of the Society at Cincinnati, be published in PHYTOPATHOLOGY and that the manuscript be held in type four months in order to give those who wish copies an opportunity to purchase them from Science Press Printing Company, Lancaster, Pennsylvania.
2. That the announcements of Tentative and Recommended Methods of the Committee on Standardization of Fungicidal Tests be published in Phytopathology as advertisements, whenever space is available, without cost to the Committee.
3. The appointment of J. G. Horsfall as the Society's representative on the A.A.A.S. Council for a two-year term.
4. The appointment of J. C. Walker as the Society's representative on the Division of Biology and Agriculture, National Research Council, from July 1, 1946 through 1948.
5. The appointment of A. J. Riker on the Committee on Public Relations.
6. The appointment of H. R. McLarty on the Committee on Nomenclature and

Classification of Plant Viruses in place of H. Earl Thomas, who was appointed last year but refused to serve.

7. That the Secretary write Mrs. L. R. Jones a letter, on behalf of the Society, expressing the Society's appreciation of the bequest of $100 to the Society, left by the late L. R. Jones.

8. The establishment of a Special Committee on Coordination of Field Tests with New Fungicidal Dusts and Sprays, and that J. D. Wilson be appointed chairman with the power to name his committee.

9. That the Tobacco Disease Council be asked to study the possibilities of eradication of blue mold of tobacco and make recommendations to the Council of The American Phytopathological Society.

10. That it be the sentiment of The American Phytopathological Society that a means of affiliation of Phytopathological Societies in other countries be provided for in the revised Constitution, provided such societies wish to affiliate. That each affiliate be given the minimum of privilege of representation on the Council. That the proceedings of such affiliates be published in Phytopathology at the Society's expense.

11. That the name of the New England Division be changed to the North Eastern Division, as set forth in a petition presented to the Council.

12. That the 38th annual meeting be held Saturday, December 28, through Monday, December 30, 1946, in Cincinnati, Ohio, in Cleveland, Ohio, or in Chicago, Illinois.

ANNOUNCEMENT

The thirty-eighth meeting of the American Phytopathological Society will be held at the Netherland Plaza Hotel, Cincinnati, Ohio, December 28–30, 1946.

JAMES PETER JOLIVETTE

July 20, 1915–February 2, 1945

James Peter Jolivette was graduated from the University of Wisconsin in 1937 with the degree of Bachelor of Science in Agriculture, and in 1941 he received the degree of Doctor of Philosophy from the same institution.

From 1941 to March 20, 1942, he was Instructor in Plant Pathology, University of Wisconsin, in charge of the truck crop disease field laboratory at Kenosha, Wisconsin. During his college days, he was in the Reserve Officers' Training Corps. When he graduated in 1937, he was commissioned as Second Lieutenant, and in 1941, First Lieutenant, in the Officers' Reserve Corps, U. S. Army. He was called into active military service March 20, 1942. From May, 1943, until his untimely death on Luzon, P. I., by enemy fire, he was Captain of his Company, Co. L, 20th Infantry, 6th Division, U. S. Army.

As an investigator in his chosen field of plant pathology, Dr. Jolivette showed marked ability and originality, both in fundamental research and in its practical applications. As a soldier, his courage and leadership were an inspiration to his men. The memory of him as a soldier, as a scientist, and as a man will continue to be a lasting inspiration, especially to those who were fortunate enough to know him.

ALBERT EDWARD EDGECOMBE

February 5, 1897–March 30, 1945

Albert Edward Edgecombe was graduated from Queens University (Ontario) in 1923 with the degree of Bachelor of Arts, and in 1929 he received the degree of Doctor of Philosophy from the University of Chicago.

From 1929 to 1939 he served as Assistant Professor of Botany and as Associate Professor from 1939 till his death, all at Northwestern University. His special field was mycology, and his researches dealt with certain rusts and dermatophytic fungi. His teaching activities covered a wide variety of botanical subjects.

Dr. Edgecombe was a charter member of the Mycological Society of America and a member of several other scientific organizations. He was a man of high standards, both in research and in teaching, of indefatigable industry, and of broad interests. He believed that assiduity should be a chief criterion of one's success.

LEWIS RALPH JONES

December 5, 1864–April 1, 1945

Born and reared on a Wisconsin farm, Lewis Ralph Jones later attended Ripon College and the University of Michigan (Ph.B., 1889), taught "natural science" at Mount Morris Academy, Illinois, and in 1889 became Instructor in Natural History at the University of Vermont. Here he was rapidly advanced to assistant and associate professorships, becoming full Professor of Botany in 1893. He was appointed Botanist of the Agricultural Experiment Station in 1889, and continued in these two capacities until he left Vermont in 1910 to found a department of plant pathology in his home State university. Organized for research and training of men and women to carry on the torch of discovery, his new department rapidly became a mecca for graduate students. Professor Jones retired from active service in 1935, but continued his important responsibilities in the National Academy of Sciences and as committeeman, trustee, and counselor.

Of degrees and honors Dr. Jones had many—the much coveted honorary doctorate from Cambridge University (Sc.D., 1930), and others from the universities of Vermont (Sc.D., 1910), Wisconsin (Sc.D., 1936), and Michigan (Ph.D., 1904; LL.D., 1935). He held world-wide memberships in over twenty scientific organizations—with high offices in ten or more. He was one of the chief organizers of the Vermont Botanical Club, Forestry Association of Vermont, Boyce Thompson Institute, Tropical Plant Research Foundation, and American Phytopathological Society and a leading spirit in the Botanical Society of America. In his chosen field of plant pathology, he was the prime mover in the national society, its guardian and guide throughout the formative early years, its first president (1909), and the first editor-in-chief of its official journal PHYTOPATHOLOGY (1911–14).

Jones was pre-eminent as a researcher. Among the more outstanding of his contributions are those on Bordeaux mixture, potato diseases, sap flow in sugar maple, bacterial soft rot of vegetables, the nature and control of diseases in plants, the development of resistant varieties, and the effects of environment on infection and pathogenesis.

Professor Jones held the rare distinction of standing high not only as researcher, but also as practical agriculturist, organizer, administrator, and teacher. It is as a teacher, however, that his influence will perhaps extend furthest and last longest: first because of the man himself, and second because he knew that he could best serve his time by developing men, programs, and institutions—he was above all a human catalyzer of ideas and ideals. To sit under his tutelage was a liberal education in itself; he taught science "with a difference."

MERTON BENWAY WAITE

January 23, 1865–June 5, 1945

Merton Benway Waite was graduated from the University of Illinois in 1887 with the degree of Bachelor of Science, and in 1919 the University of Maryland conferred on him the degree of Doctor of Agriculture.

From 1887 to 1888, Dr. Waite served as assistant to Dr. T. J. Burrill at the University of Illinois. From 1888 to the time of his retirement in 1935, Dr. Waite was employed in the U. S. Department of Agriculture, at first with Dr. B. T. Galloway in the old Section of Vegetable Pathology and later as head of the Office or Division of Fruit Disease Investigations, in the Bureau of Plant Industry. From 1930 to 1938, he was a lecturer on plant diseases and from 1932 to 1938, also on plant ecology, in the Graduate School of the Department of Agriculture.

Dr. Waite was a charter member of The American Phytopathological Society and a member of a number of other scientific organizations. He was an unusually keen observer, an enthusiastic, inspiring leader, with a wealth of knowledge, clear vision, and well-balanced judgment. His scientific attainments are recognized the world over and are a continuing memorial to him. His genial smile and cordial greeting will be greatly missed by his many friends.

LEON HATCHIG LEONIAN

February 27, 1888–June 7, 1945

Leon Hatchig Leonian was graduated from the University of Kentucky in 1916 with the degree of Bachelor of Science and, from the University of Michigan, he received the degree of Master of Science in 1917 and the degree of Doctor of Philosophy in 1922.

Dr. Leonian served successively as Assistant Research Horticulturist at Clemson College Agricultural Experiment Station, 1917–18; Assistant Professor of Botany and Plant Pathology at New Mexico State College and Experiment Station 1918–1922 (part time); and in the College of Agriculture and Agricultural Experiment Station of West Virginia University, as Assistant Professor of Plant Pathology from 1922 to 1926; Associate Professor of Plant Pathology, 1927–1936; and Professor of Mycology and Mycologist, from 1936 to the time of his death.

As a researcher, Dr. Leonian did notable work, particularly on the physiology of fungi, and as a teacher, he was a favorite with his students. His frank ways and pleasant smile will be greatly missed by his many friends and associates.

CHALMERS JACKSON KING

October 26, 1893–October 17, 1945

Chalmers Jackson King was graduated from Clemson College in 1913 with the degree of Bachelor of Science, and pursued graduate work there in 1914.

From 1914 to 1916 he was Instructor in Soils at Clemson College and Assistant Chemist in the South Carolina Agricultural Experiment Station. He went to Arizona in 1917 as Assistant in Biophysical Investigations with the Bureau of Plant Industry, U. S. Department of Agriculture. In this position through 1920 he conducted research in cotton and citrus nutrition and water requirements. From 1921 until his death he was Superintendent of the U. S. Cotton Field Station at Sacaton, Arizona. Under his direction Sacaton became an important center for cotton research. From 1935 on, he was in charge of the Federal program of cotton research in the Southwestern States.

"C. J.", as he was familiarly known to his associates and to cotton producers throughout Arizona, California, New Mexico, and west Texas, devised practical control measures for the crazy-top disorder of cotton, for Phymatotrichum root rot, and for other diseases under irrigated conditions. He contributed much to his associates in inspiring interest in cotton research and to cotton producers in helping them to understand and to overcome practical production problems.

RODNEY BEECHER HARVEY

May 26, 1890–November 4, 1945

Rodney Beecher Harvey was a graduate in the pharmacy course at Purdue University in 1912 and was graduated from the University of Michigan in 1915 with the degree of Bachelor of Science. In 1918, he received the degree of Doctor of Philosophy from the University of Chicago and the honorary degree of Doctor of Science from Purdue University in 1939.

Dr. Harvey served as Assistant Botanist, Eli Lilly and Company, 1912–13; Assistant Botanist, University of Michigan, 1915; Microanalyst, 1915–1919, and Physiologist, 1919–1920, Bureau of Plant Industry, U. S. Department of Agriculture; and at the University of Minnesota and Agricultural Experiment Station he served as Assistant Professor of Plant Physiology, 1920–1923; Associate Professor of Plant Physiology, 1923–1929; Associate Professor of Plant Physiology, Agricultural Botany, and Horticulture, 1929–1930; and Professor of Plant Physiology from 1931 to the time of his death, except certain periods while on temporary leave. During 1936–37, he served as Director of the Citrus Laboratory, Dunedin, Florida; and during 1942–43, he was Director, Division of Industrial Microbiology, General Mills.

He was honored by being granted a Guggenheim Memorial Foundation Fellowship, 1927–28. He was a charter Member of the American Society of Plant Physiologists (Secretary, 1923–25; Vice-president, 1931; President, 1936; and Executive Committee, 1937–). He was a member also of the Botanical Society of America, Ecological Society, and the American Phytopathological Society.

Dr. Harvey did notable work on a wide range of problems in the field of plant physiology. Some of these that have close relation to plant pathology are: absorption of electrolytes by plants; enzymes of respiration; reactions of protoplasm to low temperatures; ethylene ripening of fruit; and the nature of toxic action. He was a progressive thinker and was unusually active in whatever he undertook.